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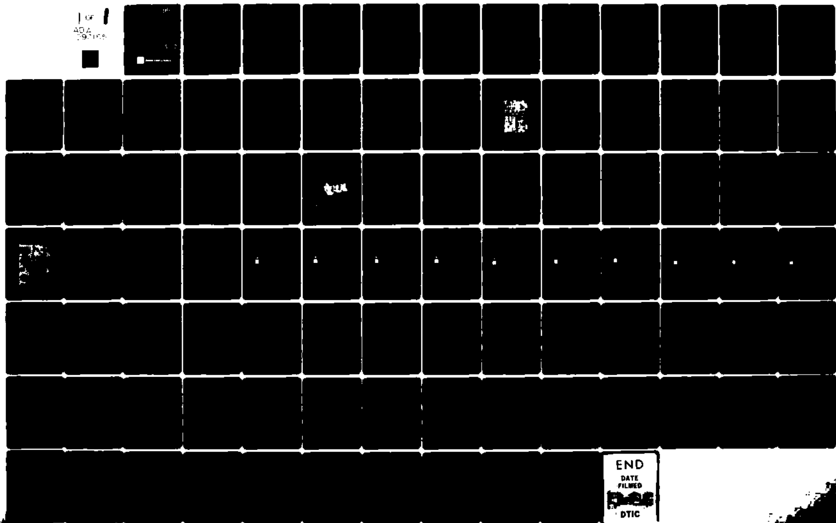

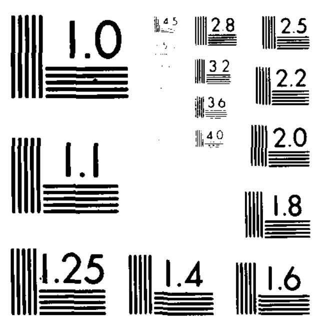

MICROCOPY RESOLUTION TEST CHART

R80-142

OCTOBER 1980

(18) LEVEL II

AD A097165

FINAL REPORT

15kW GENERAL PURPOSE POWER CONDITIONER

(FREQUENCY CHANGER)

INVERTER/CONVERTER INTEGRATION

CONTRACT DAAK 70-77-C-0157

Prepared for

U.S. ARMY MOBILITY EQUIPMENT RESEARCH and DEVELOPMENT COMMAND
Fort Belvoir, Virginia

Delco Electronics

General Motors Corporation
- Santa Barbara Operations
Santa Barbara, California

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Contract Initiated: *September 1977*

Prelim. Design Completed: *March 1978*

Inverter Fabrication/Assembly Completed: *October 1978*
Inverter/Converter Integration Completed: *November 1979*

Project Engineer: *A.H. Barrett, Delco Electronics*

Program Manager: *R.F. Brewster, Delco Electronics*

Contracting Officer's
Representative: *R. Williams, MERADCOM*

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PREFACE

The work reported herein was performed by Delco Electronics Division, Santa Barbara Operations, under contract to the United States Army Mobility Equipment Research and Development Command (Contract DAAK70-77-C-0157). The Contracting Officer's Representative is Robert Williams at Fort Belvoir, Virginia.

This report is the final report of effort associated with development of the 15kW General Purpose Power Conditioner. Since this is the Final Report, a summary of tasks previously covered by the following Interim Reports is provided.

1. Inverter Preliminary Design (R78-67, July 1978)
2. Inverter Fabrication & Assembly (R78-117, October 1978).

The main body of the report, however, concentrates upon the Inverter/Converter Integration phase of the contract, a phase which has not previously been reported. The integration effort was started in November 1978 and finished in November of 1979 and was followed by successful completion of the required Performance and Endurance Tests as reported in test report R80-122, dated September 1980.

SECTION I
INTRODUCTION

This report covers effort under Contract DAAK70-77-C-0157. The contract requires that Delco Electronics — Santa Barbara Operations furnish the engineering, labor, tools, services, materials, equipment, and facilities necessary to design, assemble, test, and deliver one Advanced Development Unit (per definition of MIL-STD-280A) Inverter Section for a 15 kW General Purpose Power Conditioner Unit (PCU) in general accordance with Purchase Description EED 76061101, "Inverter Section of 15 kW General Purpose Power Conditioner," dated October 1976, and as amended by Addendum 1, dated January 1977.

The required effort was originally proposed by Delco as an integrated program that assumed concurrent and/or serial performance of various tasks to achieve coherence and cost effectivity. Due to FY 1978 funding limitations the contract was awarded on an incremental funding basis and required a shift in performance schedules. The initial funding increment was directed toward the first contract line item, CLIN 0001, Preliminary Design, which was completed in March 1978, and recorded in the first interim report (R78-67, dated July 1978) after funding for selected data items was released in May 1978. The Preliminary Design effort involved breadboard inverter development to overcome performance deficiencies previously encountered in MERADCOM testing of Delco inverters; cost tradeoff investigations of three different ways of implementing the new inverter; final inverter design and mechanical/thermal packaging of the recommended approach; and preliminary frequency changer layout showing integration of the recommended inverter with the ac-to-dc converter developed by Delco under separate contract (DAAK70-77-C-0035) as reported in Final Report, R78-28, dated April 1978. The CLIN 0001 effort resulted in MERADCOM approval to proceed with CLIN 0002, Inverter Fabrication and Assembly, using the design recommended and established during preliminary design.

Upon receiving MERADCOM approval for CLIN 0002, all drawings and lists generated during final design were released to the fabrication and assembly cycle. The second interim report (R78-117, dated October 1978) provided the details of the results of that

effort. Section II of that report provided circuit schematics and photographs of the inverter control circuit card assemblies (CCA's). Section III included the power circuit schematic, the modular divisions established during the packaging effort, and photographs showing the mechanical/electrical features of the five separate power module assemblies. Section IV provided an update of CLIN 0001 concepts concerning the configuration for the completed power conditioner or frequency changer. The update showed the overall enclosure concept and provided a new weight estimate which included the actual weights of those internal modules which were fabricated/assembled under CLIN 0002 and/or under the earlier converter development contract (DAAK70-77-C-0035).

MERADCOM approval of the CLIN 0002 effort and the associated interim report resulted in release of funds (November 1978) to proceed with CLIN 0003, Inverter/Converter Integration. CLIN 0003 required design, development, fabrication, and assembly of all system support functions including the enclosure and auxiliary power supplies as well as all start-up and protection control circuits.

Following a brief summary of CLIN 0001 and CLIN 0002 efforts in Section II, this report presents the CLIN 0003 integration details as Section III. The section includes system aspects, provides overall functional block diagrams, and presents schematics and details of the newly developed control circuits. Section IV of the report provides a summary of the power conditioner performance and endurance tests and Section V presents Delco's recommendations concerning items to be considered for future Engineering Development.

SECTION II
PRIOR CONTRACT EFFORT
(CLIN 0001 & 0002 Summary)

2.1 INTRODUCTION

The work and services under contract DAAK70-77-C-0157 required that, as Contract Line Item CLIN 0001, a preliminary design effort be performed and approved by MERADCOM before proceeding with CLIN 0002, Inverter Fabrication and Assembly. The Delco effort under these two contract line items is summarized in the following pages. Details of the effort may be found in Delco interim reports R78-67, Preliminary Design, and R78-117, Inverter Fabrication and Assembly, submitted in July 1978 and October 1978, respectively.

2.2 PRELIMINARY DESIGN (CLIN 0001)

Compliance with CLIN 0001 required that tradeoff investigations into methods of implementing the Delco power center inverter be performed. The study was to trade off the use of capacitors versus solid state devices in the inverter design and to project production cost estimates for the designs evolved. A basic overriding criteria for the designs considered was that the performance deficiencies evident with previous Army/Delco developed power center inverters be overcome.

Previous Delco effort under Contract DAAK02-72-C-0210 had provided a breadboard system which established the feasibility of using the Delco power center inverter coupled with an ac-to-dc resonant converter for the 15 kW General Purpose Power Conditioner (frequency changer). MERADCOM testing of that breadboard system revealed major performance deficiencies attributable to the ac-to-dc converter and minor deficiencies which could be ascribed to the inverter.

The ac-to-dc converter has been redesigned, fabricated, and tested by Delco under a separate contract (DAAK70-77-C-0035). Performance capability substantially meeting Army Purchase Description (PD) requirements has been reported in Delco Test Report R78-28, dated March 1978, and Final Report R78-38, dated April 1978, under that contract.

The power center inverter performance deficiencies were corrected under the contract effort reported herein and were associated with the following:

- Failure to meet voltage waveform harmonic distortion requirements
- Inverter instabilities due to triplen inductor saturation under certain load transients
- Inverter commutation failures under two-per-unit loading.

Solution of these inverter problems resulted through implementation of a 20-step inverter internal line-to-neutral waveform and use of a new, more cost effective commutation scheme. The previous breadboard inverter used a 16-step waveform and required 32 SCR's. The new inverter provides added steps (thus, lower voltage waveform harmonic distortion) while requiring only 28 SCR's.

Beyond correcting the inverter performance deficiencies, the Preliminary Design effort included cost tradeoff investigations of three different ways of implementing the new inverter. The investigations concentrated upon methods of replacing capacitors with solid state switches (SCR's or transistors) and resulted in recommendation (and subsequent MERADCOM approval) of the inverter configuration successfully used by Delco in a previous Army funded program (Firefinder). The recommendation was based upon both cost and a development status considerations.

As part of the Preliminary Design, production cost projections for the alternate configurations considered were attempted. The approach used indicated that the recommended or baseline inverter may cost approximately $15,600 per unit if a production buy were tooled and released for 1,000 units at a rate of 30 units per month. The indicated figure included material, hands-on-hardware labor, and profit. It assumed a 90% learning curve in the production cycle and was stated in December 1977 dollars.

The information and conclusions which resulted from the tradeoff studies and through correction of the inverter deficiencies were presented to MERADCOM during a design review at Delco during the first week of February 1978. The review resulted in formal approval to proceed with the final design of the baseline inverter. The final design required modification of control circuit schematics and parts lists used in the Firefinder inverter and a complete mechanical/thermal/packaging redesign of the inverter circuits

for dual frequency, higher power operations. Subsequent to the completion of the final design, MERADCOM provided authorization and funds to proceed with CLIN 0002 of the contract.

2.3 INVERTER FABRICATION AND ASSEMBLY (CLIN 0002)

Upon receiving MERADCOM approval for CLIN 0002, all drawings and lists generated during final design were released to the fabrication and assembly cycle. The released inverter consisted of three circuit card assemblies (CCA's) and five power circuit modules. A brief description of each of these assemblies is provided below. Note that the assembly numbers provided agree with the Family Tree breakdown included as Figure 1 in Section III of this report and have been updated from the assembly numbers used in the previous reports.

2.3.1 WAVEFORM GENERATOR CCA (A-18)

The waveform generator CCA contains the circuitry necessary to develop the SCR drive timing pulses, as well as the circuitry necessary to synchronize output phases when two similar power center inverters are operated in parallel. The major portion of the waveform generator circuit was unchanged from a first generation Firefinder CCA; therefore, Delco utilized the printed wire board (PWB) previously evolved and modified the board as necessary to include a dual frequency capability. The resulting CCA is 11.0 inches long by 9.5 inches wide and weighs 18 ounces.

2.3.2 SCR DRIVER CCA (A-19)

The SCR driver assembly accepts logic or drive pulses from the waveform generator and converts them to radio frequency (RF) bursts or triggers to be fed to separate isolation/converter circuits at or near the SCR's. This assembly is identical to the SCR driver assembly developed for the first Firefinder inverters. The driver CCA contains 28 identical SCR driver circuits assembled on a board which is 11.0 inches long by 9.5 inches wide. The CCA weighs 20 ounces.

2.3.3 SCR ISOLATOR CCA (P/N 7557961)

The inverter uses four SCR isolator CCA's which are called out as separate part numbers (P/N's) in the power module assemblies. They therefore do not have separate assembly numbers, nor do they appear on the assembly level family tree.

The isolator CCA's provide isolation between the low voltage SCR driver assembly and the high voltage SCR's in the power circuit assemblies. The assembly and interconnecting cable have been fully developed and will be used directly in both inverter and converter sections of the frequency changer. The assembly is 4.5 inches long by 3.5 inches wide and weighs 2.5 ounces.

2.3.4 T+, T- MODULE (A5)

The T+, T- module contains the power circuit components associated with the square wave inverter that operates at three times the system output frequency and drives the step-forming circuitry contained in the step forming module (A3). Interconnection with other system modules is achieved via a terminal strip on the top shelf of the module. The shelf also contains a four-channel SCR Isolator CCA (Para 2.3.3) which can be replaced without removing the module from a complete system. The module is 20-1/2 inches high by 7-5/8 inches deep by 4-5/8 inches wide and weighs 26-1/4 pounds including the CCA.

2.3.5 POWER CENTER MODULE (A4)

The Power Center Module contains the power circuit components associated with generating the broad center portion of the system's line-to-line output waveform. The circuit is essentially a six-SCR, three phase inverter plus the required two-SCR commutation circuit. The top shelf of the module contains an eight-channel SCR Isolation CCA and the terminal strip which provides interconnections to other modules. The module is 20-1/2 inches high by 7-5/8 inches deep by 4-5/8 inches wide and weighs 25-1/2 pounds.

2.3.6 STEPS/MAGNETICS MODULE (A3)

The Steps/Magnetics Module contains the ten SCR's required to form the ascending and descending steps in the output waveform, the six phase-selector SCR's which connect either the power center SCR's of A4 or the step SCR's to the output at the appropriate time, and the inverter magnetic components consisting of T1, T2, and L18. The module is 20-1/2 inches high by 7-5/8 inches deep by 4-5/8 inches wide (top), by 7 inches wide (bottom), and weighs 64-1/2 pounds. The weight is due to the heavy magnetic components, and future packaging effort should consider separating the magnetics of this section to provide more easily replaceable modules in terms of weight. The upper shelf of the module has two eight-channel SCR Isolator CCA's mounted back-to-back and an interconnect terminal strip.

2.3.7 OUTPUT FILTER MODULE (A2)

The Output Filter Module contains all of the inverter output filter and power factor correction capacitors, the contactor used to add capacitors when operating at 60 Hz, and the system output contactor. The complete module weighs 35-1/4 pounds. It is 20-1/2 inches high by 7-5/8 inches deep by 7 inches wide.

2.3.8 INPUT FILTER MODULE (A8)

The Input Filter Module contains added filter components required between the converter and the inverter. The filter includes several ac-capacitors necessary to filter out converter high frequency components and two inductors which provide added filtering and energy storage for transient loading. The module is 20-1/2 inches high by 4-1/4 inches wide by 15-1/4 inches deep. The weight of the module is 33-1/4 pounds. The upper section of the assembly provides space and securing means for installing an auxiliary power supply assembly (A24) which is presented in a later section of this report.

SECTION III
INVERTER/CONVERTER
INTEGRATION

3.1 DEVELOPMENT ASPECTS

The final development of the 15 kW Power Conditioner required integration of the power center inverter developed under this contract with the converter developed and tested under an earlier contract (DAAK70-77-C-0035). The integration involved development of all the support functions associated with combining and operating the two major subsystems as a frequency changer capable of meeting the specified requirements. It also required conversion of three converter-control breadboard circuits to printed wire board form and some relatively minor modifications to converter power modules.

Figure 1 provides a family tree which includes drawing numbers and weights for all the assemblies of the power conditioner (frequency changer). The integration phase primarily involved development of the Support Functions and the resulting assemblies are treated in detail in paragraph 3.4. A brief summary of the Inverter Group assemblies is included as paragraph 3.2 and the Converter Group control circuit and power circuit modifications are presented in paragraph 3.3.

To put the entire power conditioner in perspective, a block diagram showing interconnections and primary power/signal flow is provided in Figure 2. The block diagram is arranged to depict the relative physical location of all assemblies and terminal boards. The inverter and converter power modules and terminal boards TB2 through TB5 are made accessible by removing the unit's top cover. Removing the back plate of the unit reveals all of the control circuit card assemblies and TB1. The remaining assemblies associated with sensing circuits, control panels, input/output terminals, and cooling are available via the front of the unit.

3.2 INVERTER GROUP

The assemblies of the Inverter Group were summarized in paragraph 2.3 of this report and were covered in detail in CLIN 0002 interim report R78-117, Inverter Fabrication and Assembly. That report provided schematics, parts lists, photographs, and detailed

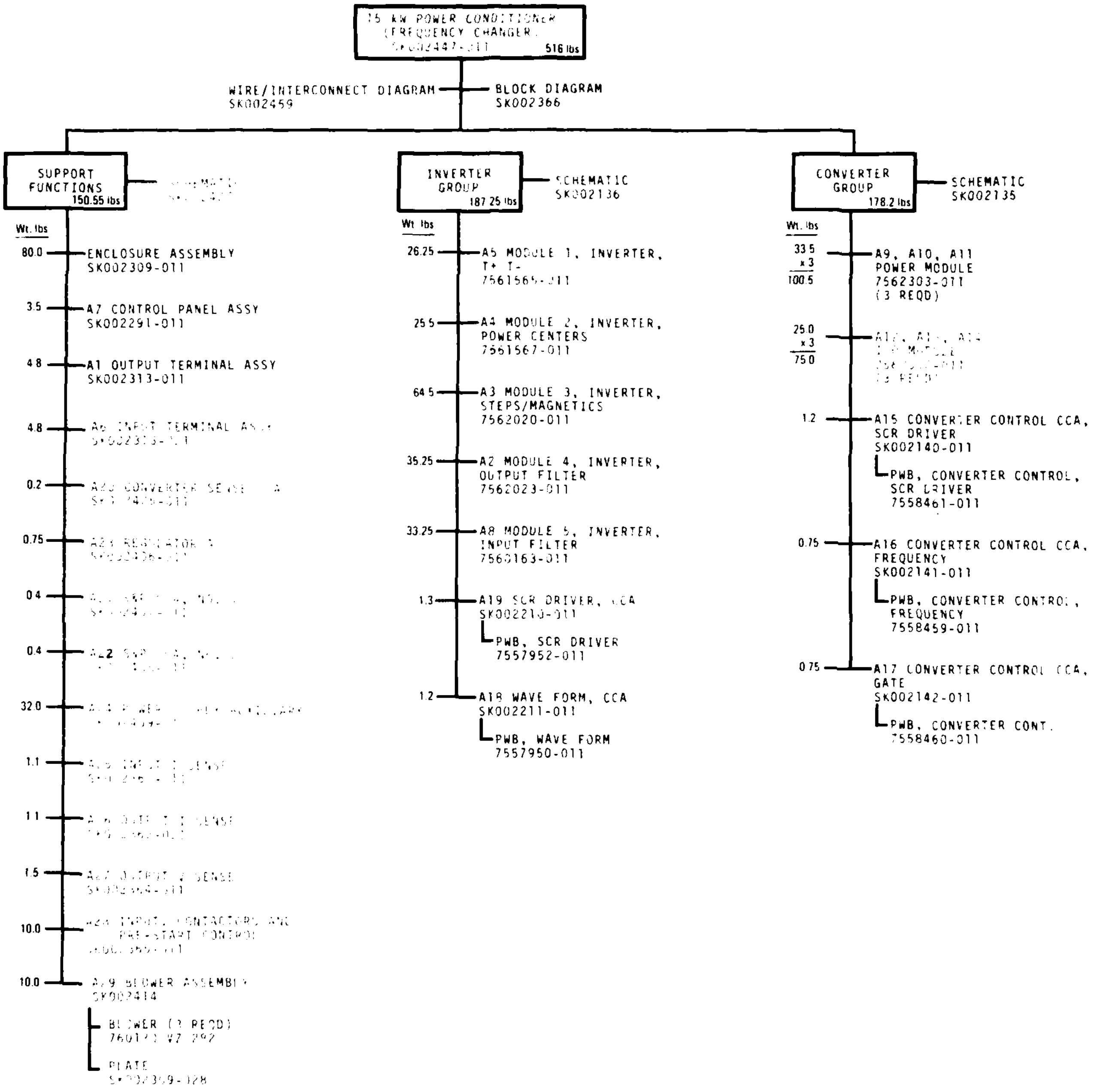
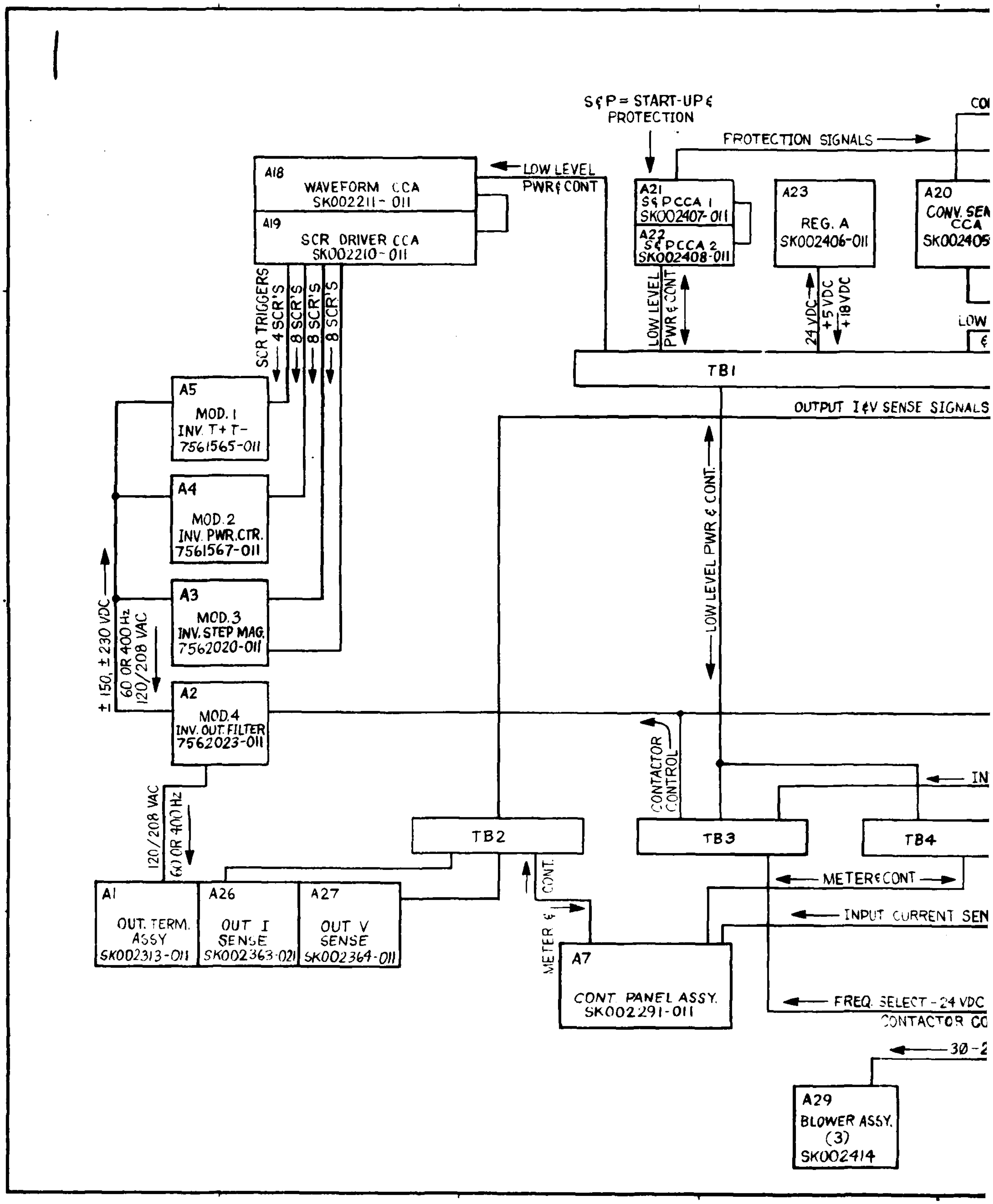


Figure 1. Family Tree, 15 kW Power Conditioner



S&P = START-UP & PROTECTION
PROTECTION SIGNALS
LOW LEVEL PWR & CONT
A18 WAVEFORM CCA SK002211-011
A19 SCR DRIVER CCA SK002210-011
A21 S&P CCA 1 SK002407-011
A22 S&P CCA 2 SK002408-011
A23 REG. A SK002406-011
A20 CONV. SEN CCA SK00240
SCR TRIGGERS
4 SCR'S
8 SCR'S
8 SCR'S
8 SCR'S
LOW LEVEL PWR & CONT
24 VDC
+5 VDC
+18 VDC
TB1
A5 MOD. 1 INV. T+ T- 7561565-011
A4 MOD. 2 INV. PWR. CTR. 7561567-011
A3 MOD. 3 INV. STEP MAG. 7562020-011
A2 MOD. 4 INV. OUT. FILTER 7562023-011
+150, ±230 VDC
60 OR 400 Hz 120/208 VAC
OUTPUT I & V SENSE SIGNALS
LOW LEVEL PWR & CONT.
CONTACTOR CONTROL
120/208 VAC
60 OR 400 Hz
TB2
TB3
TB4
METER & CONT.
METER & CONT
INPUT CURRENT SEN
FREQ. SELECT - 24 VDC
CONTACTOR CO
A1 OUT. TERM. ASSY SK002313-011
A26 OUT I SENSE SK002363-021
A27 OUT V SENSE SK002364-011
A7 CONT. PANEL ASSY. SK002291-011
A29 BLOWER ASSY. (3) SK002414

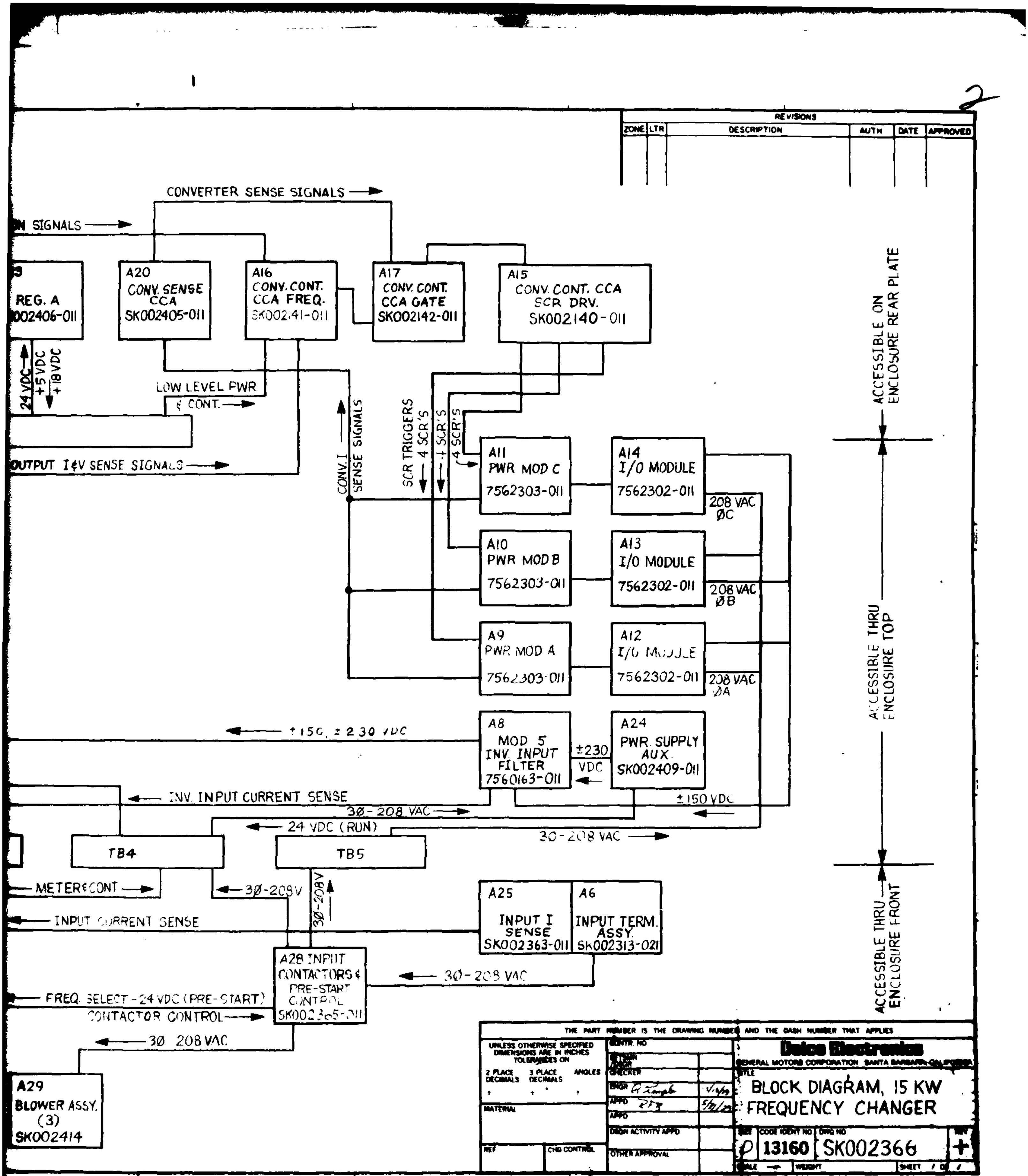


Figure 2. Block Diagram, 15kW Frequency Changer

descriptions of all modules and CCA's. The content of that report remains valid. The only change made during the integration effort was to assign assembly numbers as reflected in the family tree of Figure 1. For clarification Figure 3 is provided which shows the newly assigned power assembly numbers and their interconnects.

3.3 CONVERTER GROUP

The assemblies of the Converter Group were covered in detail in final report R78-38 of contract DAAK70-77-C-0035, dated April 1978. The report provided schematics, parts lists, and descriptions of all modules and control circuit breadboards, all of which essentially remain unchanged. The control circuits have been converted from breadboards to printed wire board format and the power modules modified slightly to remove fuses. The resulting assemblies are presented in paragraphs 3.3.1 and 3.3.2 below.

3.3.1 CONTROL CIRCUIT CCA'S

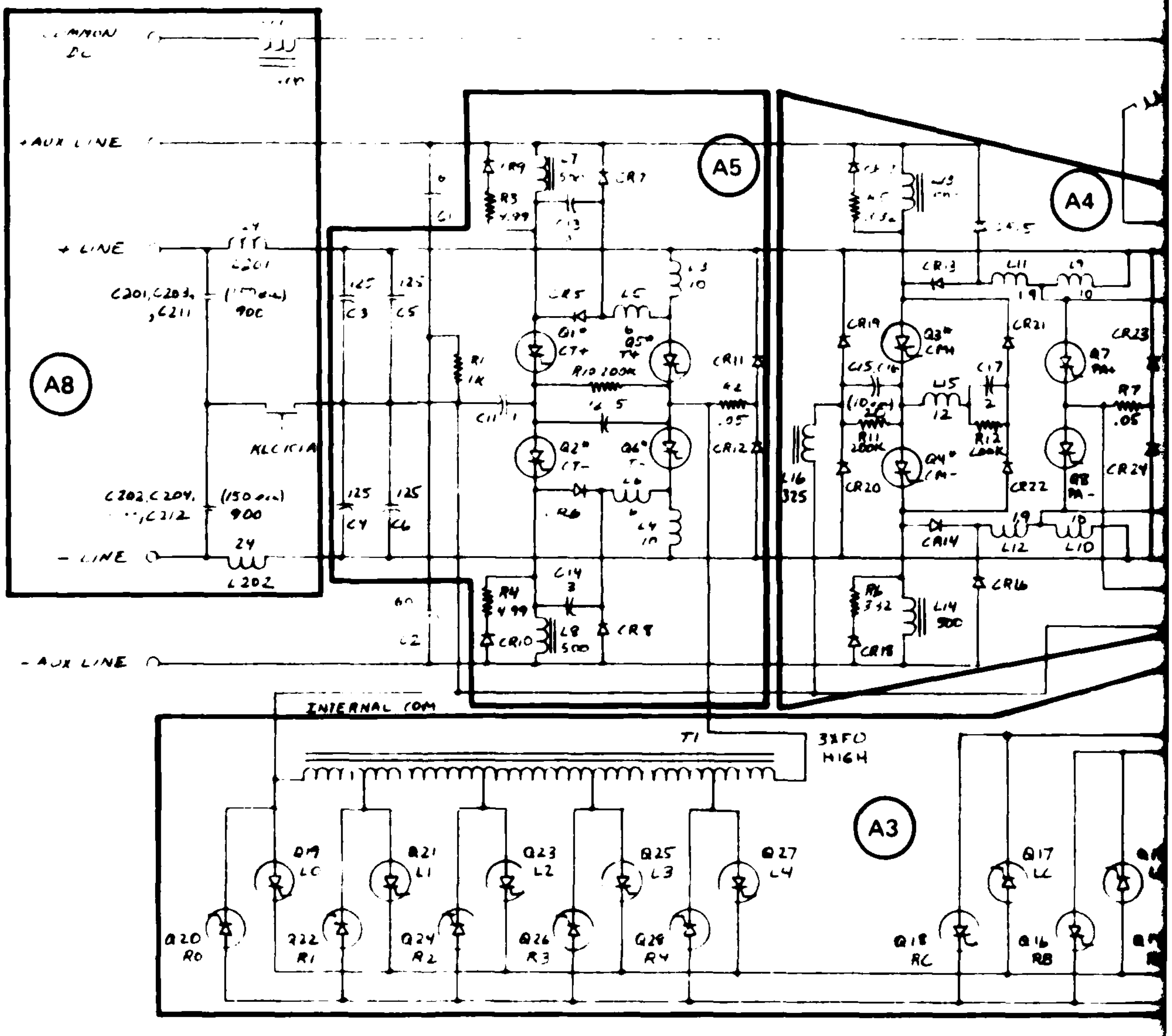
The breadboard control circuits developed previously were converted to printed wire board format under the integration effort and designated as assemblies A15, A16, and A17. Figure 4 shows the location of the various CCA's in the completed power conditioner unit. The view is of the enclosure with the top cover and back plate removed.

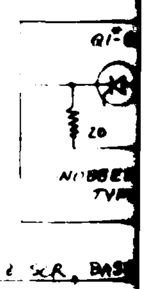
Assembly A15 is the SCR Driver Control CCA. Descriptive and schematic information for the CCA was provided in paragraph 6.5 of R78-38. The finished CCA is 11.0 inches long by 6.7 inches wide and weighs 18 ounces.

Assembly A16 is the Converter Frequency Control CCA. Descriptive and schematic information for the CCA was provided in paragraph 6.3 of R78-38. The finished CCA is 11.0 inches long by 5.7 inches wide and weighs 12 ounces.

Assembly A17 is the Converter Gate Control CCA. Descriptive and schematic information for the CCA was provided in paragraph 6.4 of R78-38. The finished CCA is 11.0 inches long by 6.7 inches wide and weighs 12 ounces.

The remaining CCA assemblies of Figure 4 are discussed in paragraph 3.4 of this report, except for A18 and A19. CCA's A18 and A19 were previously presented in R78-117 and resulted from the CLIN 0002, Inverter Fabrication and Assembly, effort of the present contract.





NOTE Ass'y. No. 4 also contains C_1 & C_2
Ass'y. No. 3 includes T_2

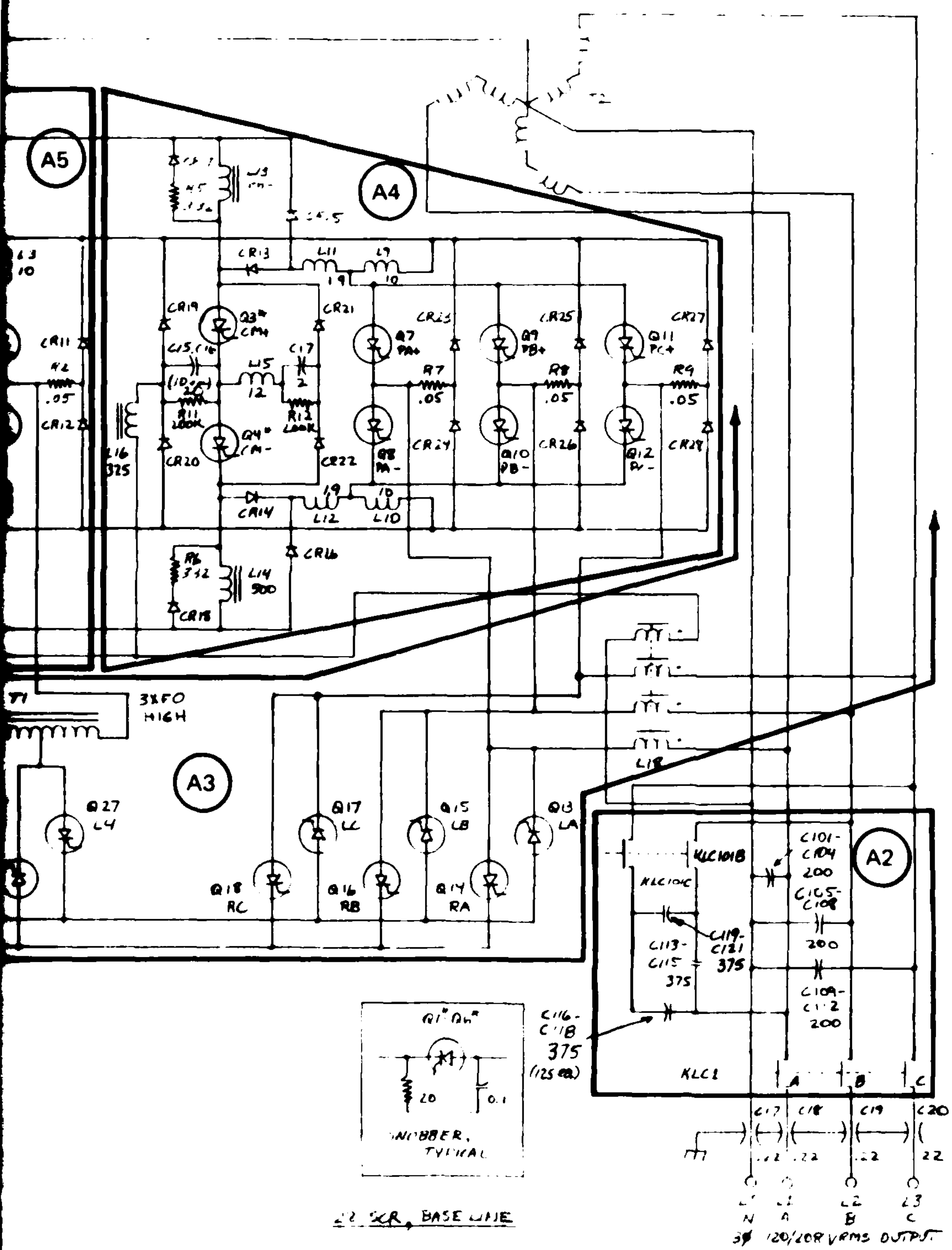


Figure 3. Inverter Po

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Figure 3. Inverter Power Assembly Divisions

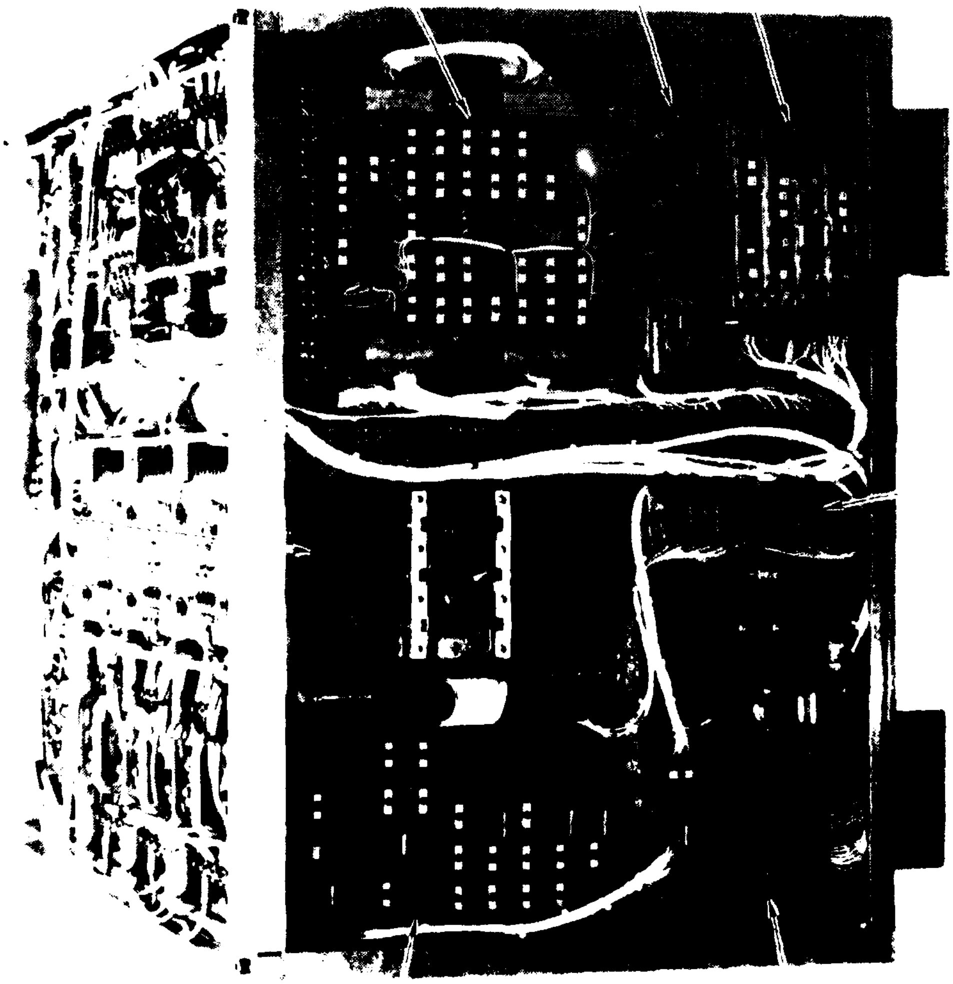


Figure 4. Power Conditioner CCA's

3.3.2 CONVERTER POWER MODULES

The converter power modules were presented in R78-38. Only minor deletions and completion alterations were made since that report. Figure 5 provides the power circuit schematic for the converter and also shows the portions of the circuit packaged in identical assemblies A9, 10, and 11, as well as identical assemblies A12, 13, and 14.

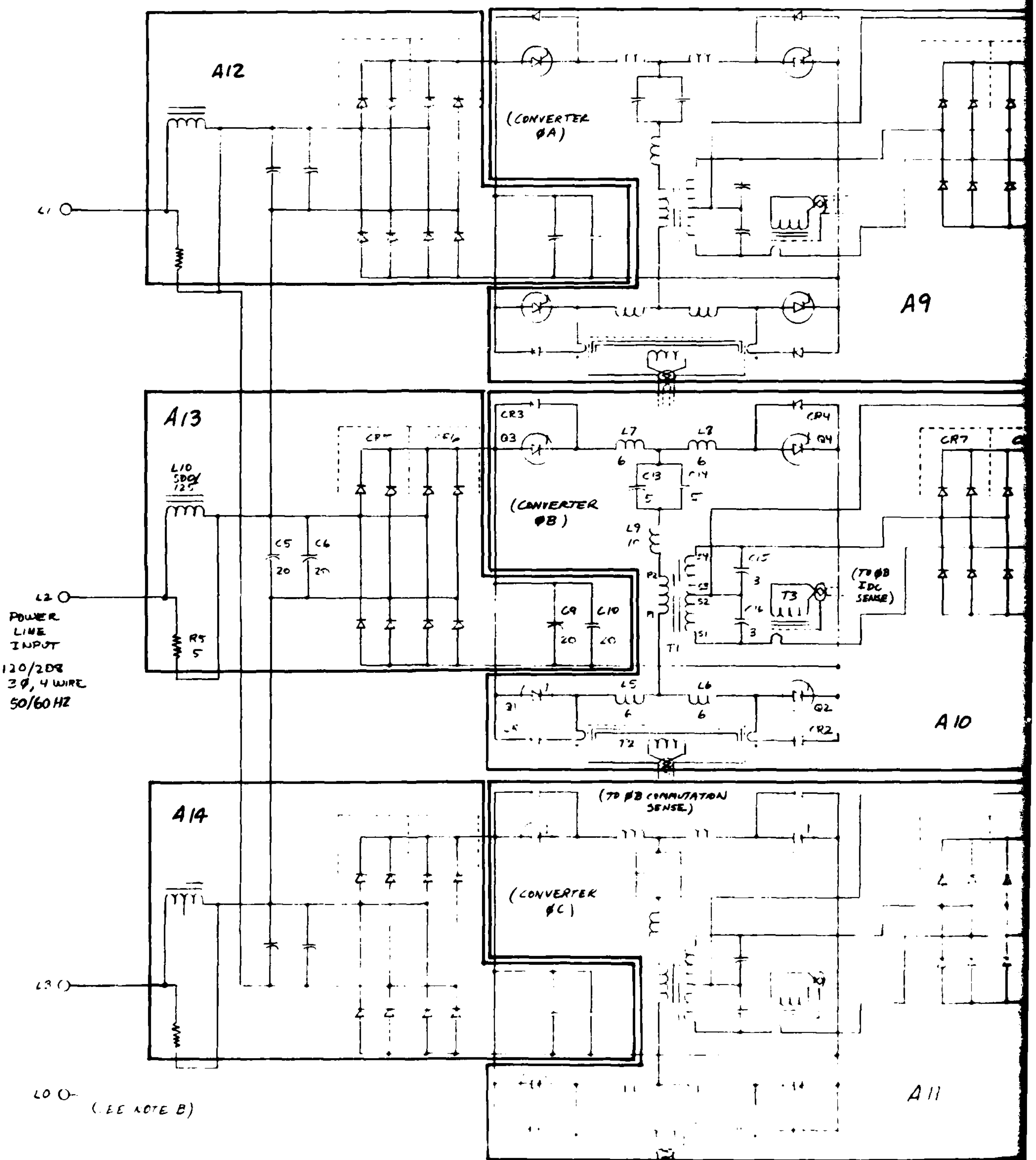
The A9, 10, and 11 assemblies are referred to as resonant converter modules. Each of these modules contains SCR's, diodes, snubber components, and passive resonant circuit components as well as the high frequency isolation transformers and output full wave bridge rectifiers. Figure 6 shows the final packaging of the resonant converter modules. The assembly is very similar to that previously reported in R78-38, except that the high frequency transformer has now been potted and mounted on a heatsink (bottom Figure 6) and handles have been added to the module to facilitate removal.

Figure 7 shows an input/output converter module (A12, 13, or 14) which contains the input LC filter components and rectifiers and the converter output filter capacitors. The module is similar to that reported in R78-38, except that a 100-ampere fuse has been deleted from the top shelf, lifting handles have been added, and the electrolytic capacitors were added on a lower shelf.

The overall outside dimensions of the two types of assemblies are the same: 5.5 inches wide, 7.5 inches deep, and 20.5 inches high. The A9, 10, or 11 assemblies weigh 25 pounds each.

3.4 SUPPORT FUNCTIONS

The primary effort during CLIN 0003, Inverter/Converter Integration, was directed to development of all of the support functions as shown by the separate assembly items under that category in Figure 1 of paragraph 3.1. Several of the newly developed assemblies relate to the system input/output (I.O.) circuits and power supplies. These functions are discussed in paragraph 3.4.1. Paragraph 3.4.2 covers the new control circuit card assemblies developed during the integration, and paragraph 3.4.3 discusses the enclosure development, including the control panel and blower assemblies. Weights for all assemblies were included in Figure 1 of paragraph 3.1.


A12
(CONVERTER ØA)
A9
A13
(CONVERTER ØB)
(TO ØB IDC SENSE)
A10
A14
(TO ØB COMMUTATION SENSE)
(CONVERTER ØC)
A11
L1
L2
L3
L0
POWER LINE INPUT
120/208 3Ø, 4 WIRE
50/60 HZ
(SEE NOTE B)

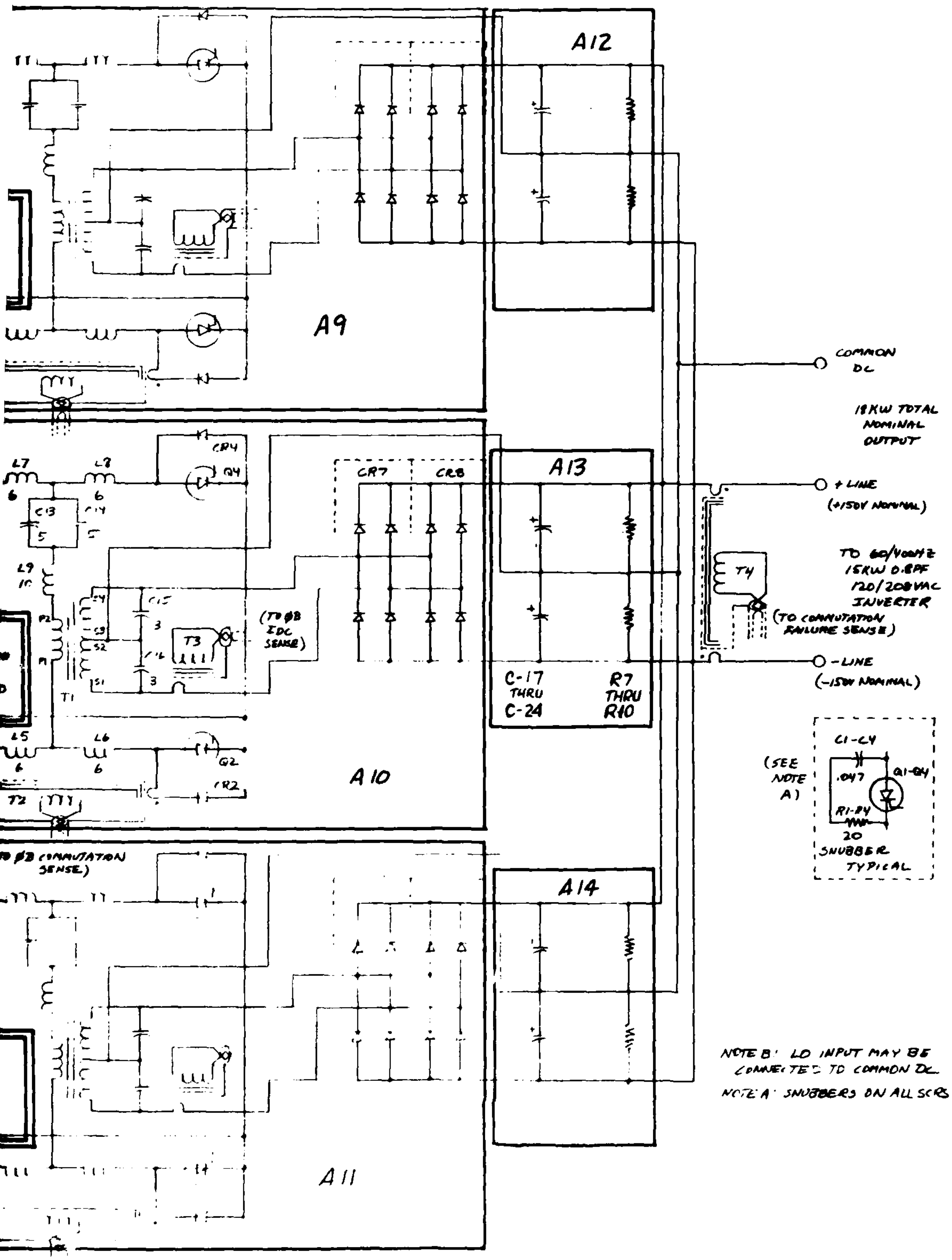


Figure 5. Thr
Pow

3

Figure 5. Three-Phase Converter
Power Assembly Division

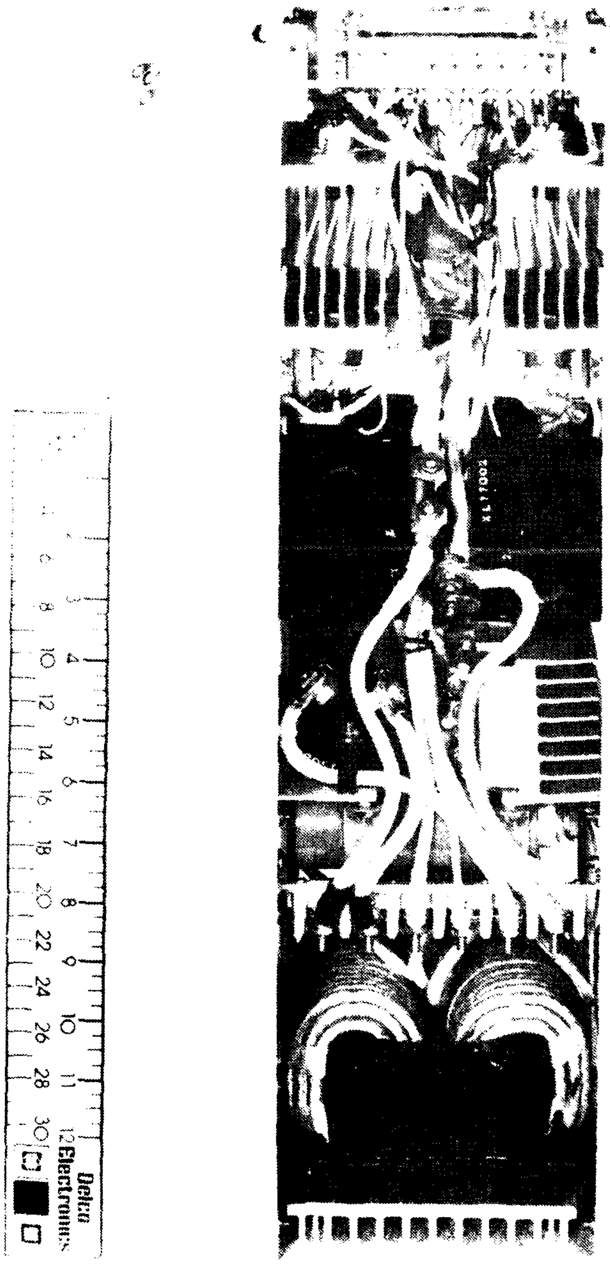


Figure 6. Resonant Converter Assembly

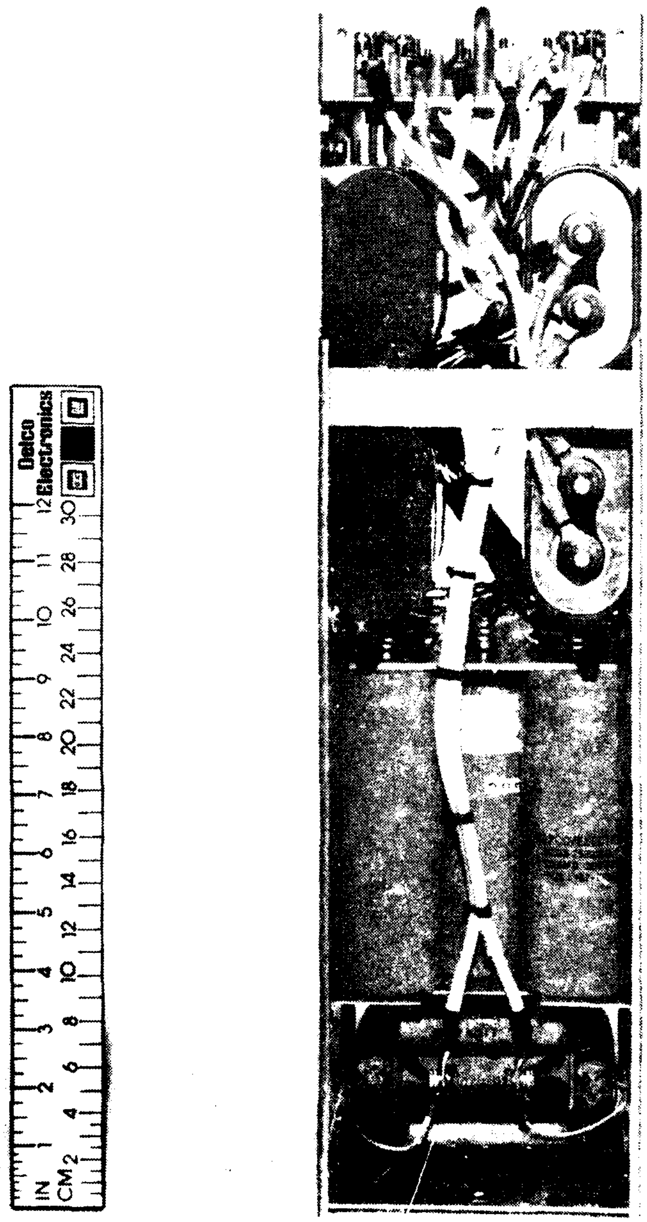


Figure 7. Input/Output Assembly

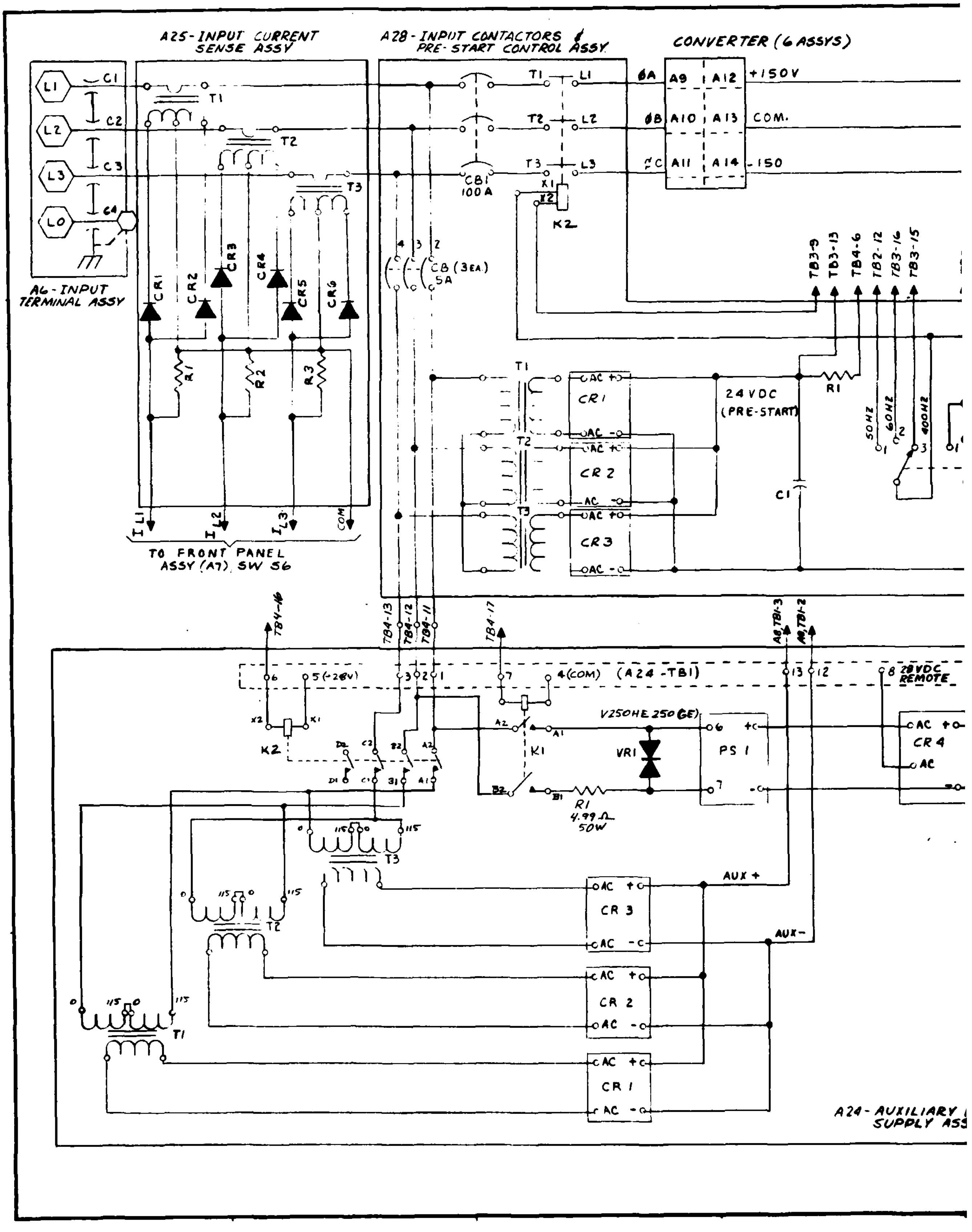
3.4.1 I. O. CIRCUITS AND POWER SUPPLIES

The relationship between the power conditioner input/output circuits, power supplies, and the inverter/converter assemblies is shown in Figure 8. The output and input terminal assemblies (A1 and A6, respectively) are identical. They contain the Army-specified split-lug connectors and the 100-ampere coaxial capacitors (C1 through C4) which reduce conducted emission currents in the output leads. The terminals are accessible via spring-return, hinged doors at the lower right and left front of the enclosure. (See paragraph 3.4.3.) A parts list for the Terminal Assemblies is included in the appendix to this report.

Just inside the terminal assemblies and physically mounted on top of them are found the input (A25) and output (A26) current sense assemblies. The assemblies contain one-turn-primary current transformers mounted on each of the voltage lines L1, L2, & L3. The many-turn secondary windings of each current transformer feed diode rectifier circuits mounted on the same board as the current transformers. The dc signals thus generated are fed to control or metering circuits as required. A wiring diagram and parts list for the current sense assemblies is included in the appendix to this report.

The output voltage sense assembly (A27) monitors the line-to-neutral voltages out of the inverter prior to the output contactor KLC1. The assembly uses small transformers in each inverter output phase, followed by diode rectifier circuits which are wired into the system control circuits. A wiring diagram and parts list for the assembly is included in the appendix.

Assembly A28, Input Contactor and Pre-Start Control, contains a 100-ampere circuit breaker (CB1) and the system's input contactor (KLC2) in the main power input lines to the converter/inverter. Low level circuit breakers (CB2, 3 and 4) provide protection for the control circuits in the system. The assembly also contains a 3-phase transformer rectifier power supply which provides 24 Vdc to all pre-start functions such as control panel illumination, malfunction, and status lamps. The 24 Vdc pre-start voltage supply is operational for all positions of the "master switch" including the "off" position. The A28 assembly also includes the system's three-position frequency select switch. The specification requires that the system provide only the 60 Hz and 400 Hz outputs. Delco has, however, included the third 50 Hz frequency for demonstration purposes and possible


A25-INPUT CURRENT SENSE ASSY
A28-INPUT CONTACTORS & PRE-START CONTROL ASSY
CONVERTER (6 ASSYS)
A6-INPUT TERMINAL ASSY
TO FRONT PANEL ASSY (A7) SW S6
24 VDC (PRE-START)
+150V
COM.
-150
CB1 100A
CB (3 EA.) 5A
50HZ
60HZ
400HZ
(A24-TB1)
V250HE 250 (GE)
R1 4.99Ω 50W
28VDC REMOTE
AUX +
AUX -
A24-AUXILIARY SUPPLY ASS

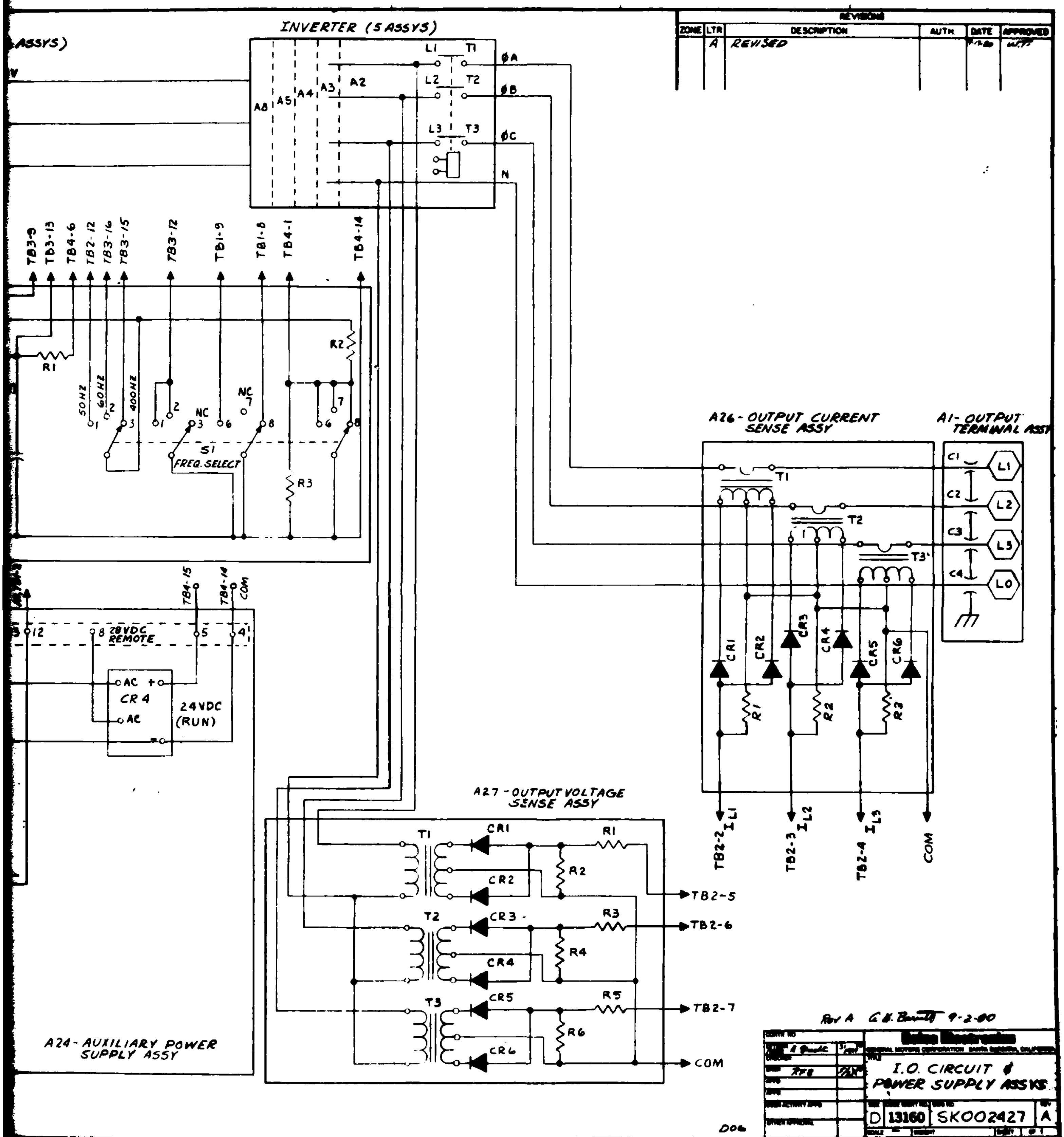


Figure 8. Input/Output Circuit and Power Supply Assemblies

consideration for future system inclusion. The ten-pound assembly has its components mounted on a 7.25 inch by 7.25 inch epoxy board. It is located at the front of the unit (see paragraph 3.4.3) below the control panel. A plexiglass cover with screw fasteners allows the operator to determine visually the status of the infrequently used circuit breakers and frequency select switch. A parts list for the assembly is provided in the appendix.

The schematic provided as Figure 8 includes a functional diagram of the A24 Auxiliary Power Supply Assembly. The auxiliary supplies become operational when the master switch is placed in the "Start" position. PS1 shown in Figure 8 is a commercially available 24 Vdc supply which operates from one phase of the input line and powers all of the low voltage control circuits in the system. In a final design phase for the power conditioner, this supply should be sized to better match the system, converted to a 3-phase input design, and possibly combined with the pre-start supply of the A28 assembly. A24 also includes a 3-phase input auxiliary supply which provides 350 Vdc for commutation of inverter SCR's when operating in a current-limiting mode. Figure 9 shows the packaged assembly with the front panel removed. Transformers T1, 2 and 3 and associated rectifiers are in the upper half of the assembly. The lower section contains the 24 Vdc commercial supply. The assembly is 4.25 inches wide, 10.4 inches high, 11.0 inches long, and weighs 32 pounds. In the unit it is physically mounted on top of A8, Inverter Input Filter, shown in Figure 14 of R78-117. A parts list is included in the appendix.

3.4.2 CONTROL CIRCUIT ASSEMBLIES

During the integration phase, four additional control circuit assemblies were developed. The physical location of the control circuits, A20, 21, 22, and 23, are shown in Figure 4, paragraph 3.3.4, and parts lists are provided in the appendix. The four CCA's have not been reduced to printed circuit board format due to the highly developmental nature of sensing and control for power conditioners.

Assembly A20, Figure 10, is the Converter Sense CCA which provides the control signals for proper operation of the converter. Transformers T2 and 3 of the schematic are located in the converter power modules A9, 10 and 11. (See Figure 5, paragraph 3.3.2.) Diode clamps are used to limit the output voltage of the commutation sense

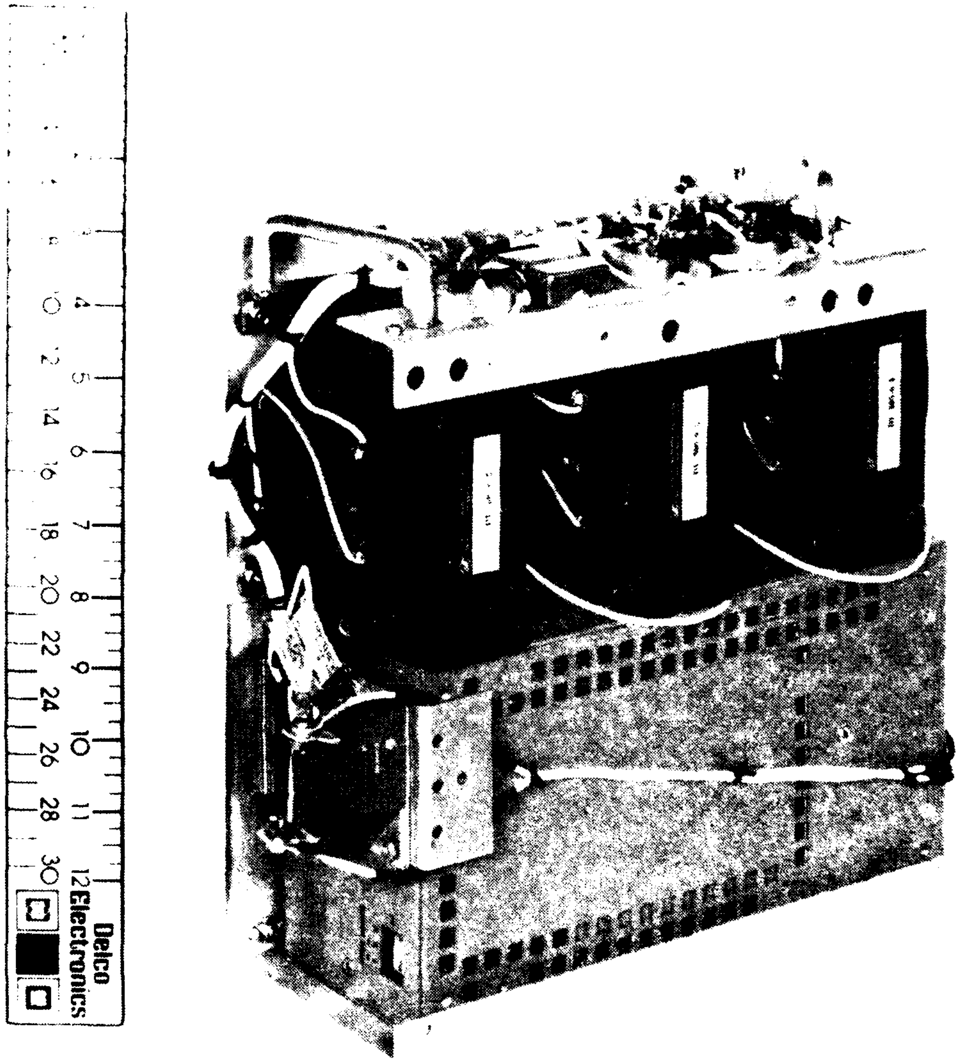


Figure 9. Auxiliary Power Supply Assembly A24

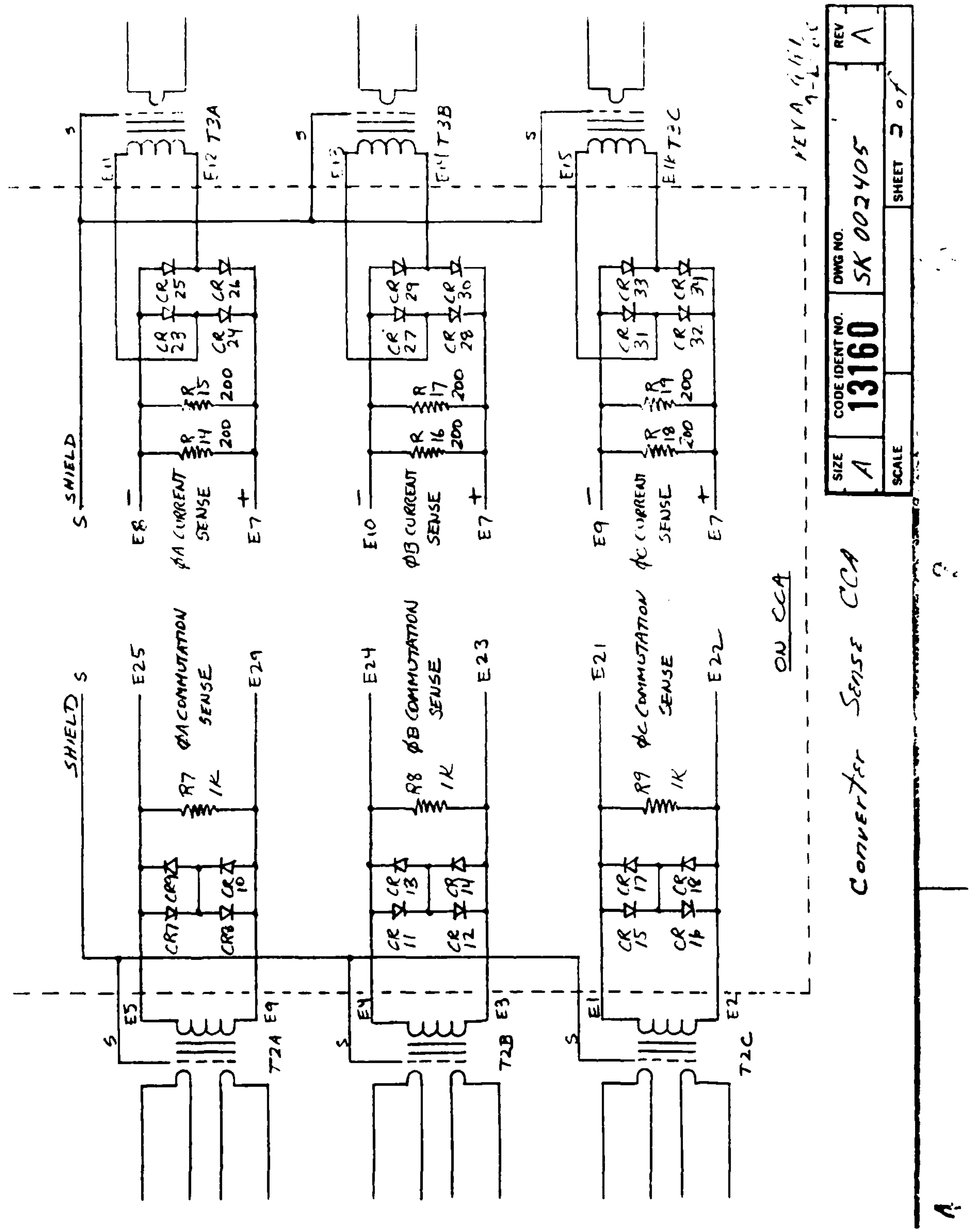


Figure 10, A20, Converter Sense CCA

transformers T2 A, B, and C. Their outputs are fed to comparators located on the converter gate control assembly A17 which sense the conduction duration of converter power module diodes and thus, SCR reverse bias time. Transformer T3, A, B, and C outputs are rectified to provide dc signals proportional to transformer primary current to A17 and are thus used as converter dc current output control signals. The assembly is 6 inches long, 2.25 inches wide, and weighs 3 ounces.

Figures 11 and 12 provide schematic diagrams of the circuitry necessary to provide the startup and protection functions for the frequency changer. Parts lists for the CCA's are included in the appendix. The CCA's (A21 and A22) are a pair of small circuit cards whose combined functions are broadly described as startup and protection. Each CCA is 6.25 inches long, 4.5 inches wide, and weighs 6 ounces. They are both low level cards which contain CMOS digital logic, operational amplifiers (some used as comparators), and relay and lamp drivers.

Input voltage to the frequency changer is sensed from the output of the prestart power supply on A28. Undervoltage (UV) is detected by the comparator A21 U7-1, 2, 3. The threshold is set by A21 R6 (nominally 98 Vrms). Overvoltage (OV) is detected by the comparator A21 U7-5, 6, 7. The threshold is set by A21 R5 (nominally 134 Vrms). Inverted malfunction signals $\overline{UV}$ and $\overline{OV}$ leave A21 and are fed to CCA A22.

An output short circuit (SC) condition is detected by A21 U7-8, 9, 10 and U7-12, 13, 14. A short circuit is detected when high output current and low output voltage with thresholds set by A21 R4 and R3, respectively, exist concurrently. The malfunction signal SC leaves A21 and is taken to A22.

Three protective features are also incorporated on A21. The first of these is sustained overload protection for the auxiliary commutation power supply. This is accomplished by using A21 U12-1, 2, 3 to detect low output voltage of the frequency changer with a threshold set by R2. The negative slope integrator using A21 U8-5, 6 is implemented such that the protective relay for this supply, A24 K2, pulls in instantaneously when the set output goes high but drops out 6 seconds after it goes low. The relay is driven by A22.

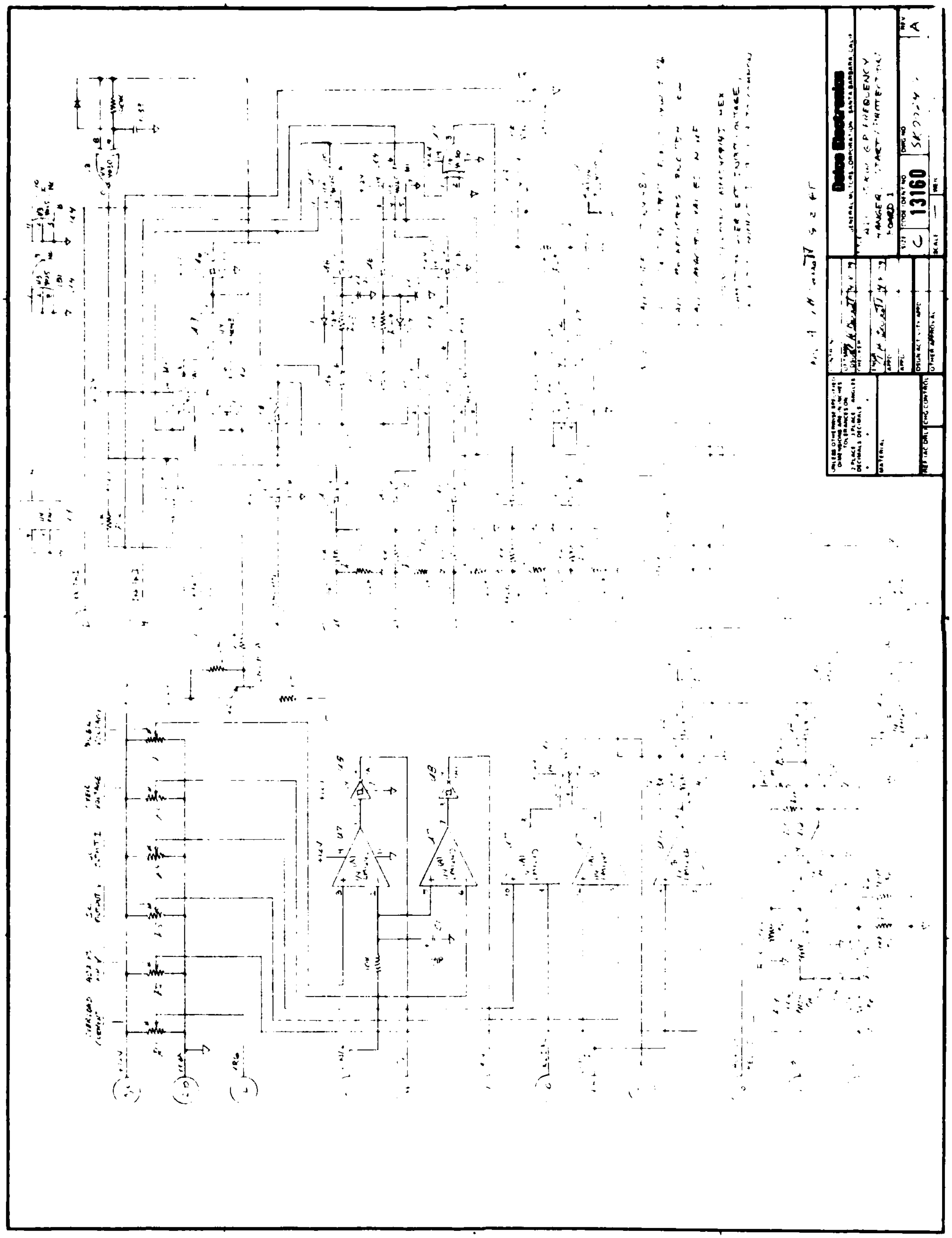


Figure 11. A-21, Start/Protect CCA No. 1

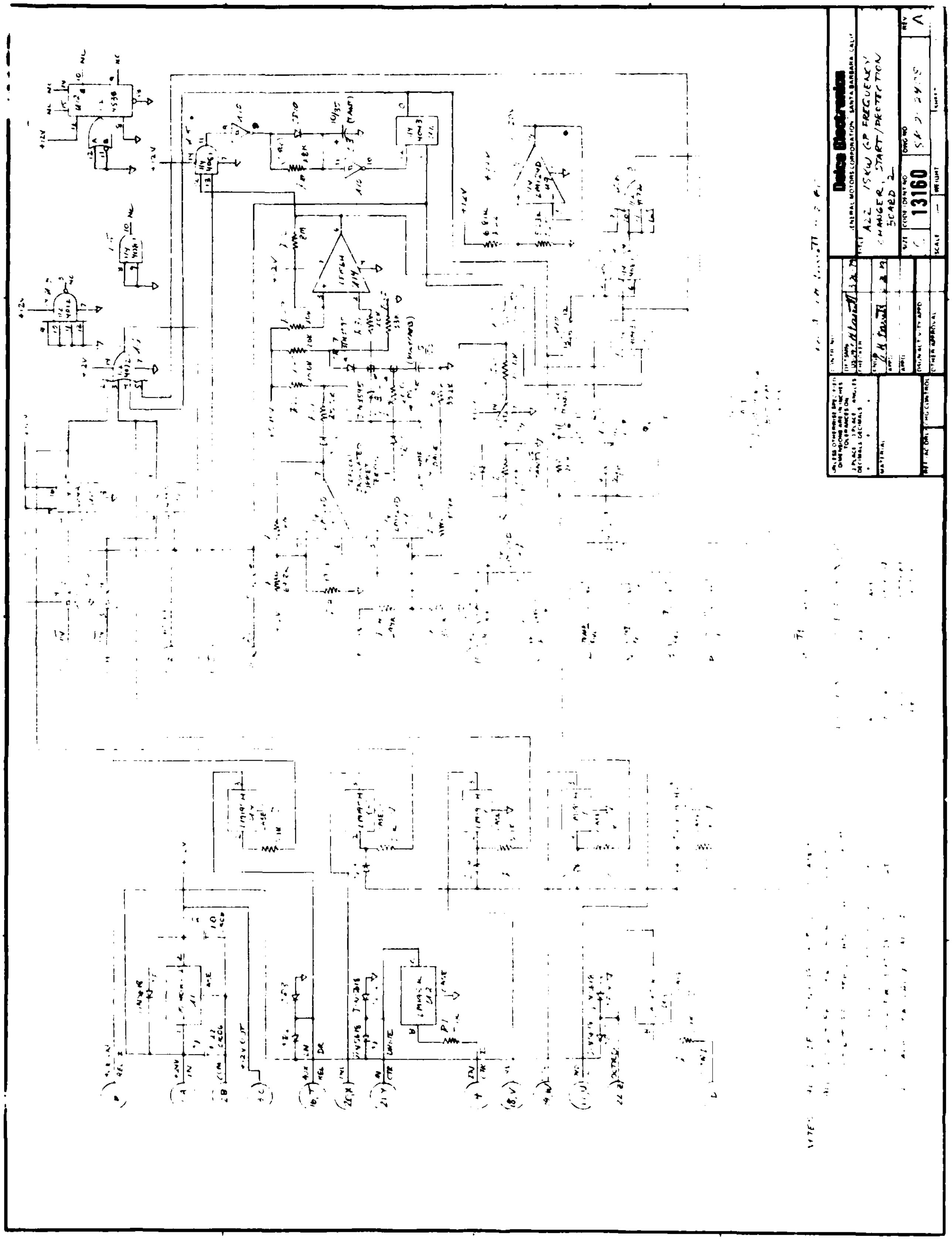


Figure 12. A-22, Start/Protect CCA No. 2

The second protective feature is overcurrent detection with set shutdown when the output current of the main 24 Vdc power supply is too high. This overcurrent is sensed by A21 U12-1, 2, 3.

The third protective feature is instantaneous shutdown should the operator attempt to change output frequency with the frequency changer operating. A21 U1-10, 11 is used to condition the frequency change signal from the frequency select switch A28 S1.

The remaining circuitry on A21 is used to accomplish an orderly startup and shutdown of the frequency changer. A21 U1-3, 4 and A21 U5-3, 4, 5, 6 are used to set the input contactor latch U9-10, 11, 12 when the MASTER switch is placed in START. The positive slope delay, A21 U6-5, 6 and U6-8, 9, causes about a 2-second delay in the closing of this contactor. The positive slope delay, A21 U6-10, 11 and U6-12, 13, makes it impossible to close the output contactor until at least 2 seconds after the input contactor has been closed. A21 U1-5, 6 and U5-1, 2, 8, 9 are used to set the output contactor latch U9-6, 7, 9 when the output CONTACTOR switch is placed in the "Closed" position. The input and output contactor latches may be set in either sequence as orderly startup is accomplished with the two positive slop delays.

Seven relay/lamp drivers are located on CCA A22. U2 is a driver for the input contactor A28 KLC2. U3 is a driver for the output contactor A2 KLC1 and the output contactor lamp located on the front panel. U4 is the auxiliary commutation power supply protective relay, A24 K2, driver. U5, U6, U7, and U8 are drivers for the "Overvoltage", "Undervoltage", "Short Circuit", and "Overload Malfunction" lamps, respectively.

A22 U9 and U14 function as an inverse time overload trip circuit. A voltage proportioned to the output current of the set is brought in at R12. This voltage is compared by U9-8, 9, 10 with an overload reference voltage VR6 from A21. If any output phase has a current of greater than 57A rms, then this comparator, through a 0.5 second delay and U12-1, 2, start the inverse time timeout. If current is greater than 57 A rms, but less than 78 A rms, 30 seconds is timed out. For currents greater than 78 Arms, but less than 110 Arms, time out is an inverse relationship, decreasing to a minimum of 9 seconds for currents greater than 110A rms.

U11-1, 14, 15 is the overload lamp latch and is set by the inverse time circuit. The overload lamp is also driven for a 5-second interval by detection of a transient overload of the regulator on CCA A1, a commutation failure of the inverter, a sustained inverter lockup, or a short shutoff detection from the converter.

U11-10, 11, 12 is the short circuit lamp latch and is set by U10-8, 9 and U10-10, 11 0.5 seconds after a short circuit is detected.

Any of the four malfunction lamp latches causes an immediate shutdown of the frequency changer by action of the OR gate U16-1, 2, 3, 4, 5 driving the shutdown circuitry on A21.

Both A21 and A22 are powered by a single +12V power supply located on A22. A22 U1 is a +12V regulator for this supply.

The circuit card assemblies (CCA's) developed during the integration phase of the program incorporate "on-board" regulators which convert the 24 Vdc from the power supply assembly, A24, to the low voltages required by the control circuits. However, CCA's A18 and A19 associated with the inverter control were developed under previous programs and do not contain on-board regulators. Figure 13 provides the schematic diagram for the A23, Regulator A, assembly which serves this function. The circuit uses standard regulator components to provide the required +18 Vdc and +5 Vdc. The circuit provides for an overcurrent signal to the startup and protection CCA, A21. The regulator assembly is 9.5 inches long, 2 inches wide, and weighs 12 ounces. A parts list for the assembly is provided in the appendix.

3.4.3 ENCLOSURE DEVELOPMENT

During the integration phase of the program the conceptual enclosure design reported in R78-117 was fully developed. Detail drawings of all parts and pieces were generated, released for fabrication and assembled into the final enclosure shown in Figure 14. The aluminum enclosure is built up from a 0.190-inch bottom plate which sets on two 2-inch by 5-inch channels designed to accept standard for lifts. Side posts and cross members are made from 1-inch by 2-inch tubing with 1-inch square tubing used for bracing. The side plates are made of 0.060 aluminum with venting louvers appropriately spaced. The

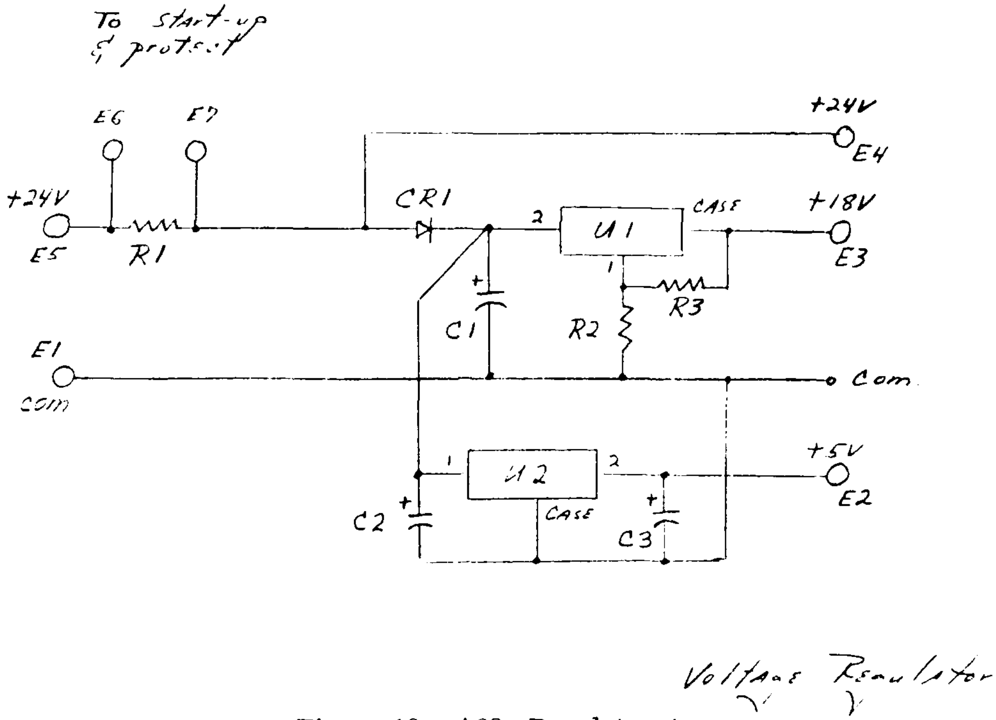


Figure 13. A23, Regulator A

cover is made of 0.090-inch aluminum reinforced with 0.060-inch x 0.5-inch angle stock along all edges. The cover overlaps the sides of the enclosure and is held down by spring clips which compress a captive gasket mounted around the perimeter of the cover. Lifting eyebolts are provided at the four upper corners of the enclosure. It should be noted that spreaders must be used when attempting to lift the 516-pound unit with a sling attached to the eyebolts.

Access to the input and output split-lug terminals is provided at the lower front corners of the enclosure via spring return, fiberglass doors. Cooling air enters the unit through an EMI-shielded air filter which extends from the top to the bottom of the unit. The blower assembly, A29, (parts list in appendix) is behind the filter.

Details of the control panel, are shown in Figure 15 and a parts list is provided in the appendix. Per the Purchase Description the control panel is provided with indicator lights for 60 Hz and 400 Hz operating modes only. As mentioned previously the frequency select switch has a third, 50 Hz, position and the unit can be operated at 50 Hz with reduced voltage outputs.

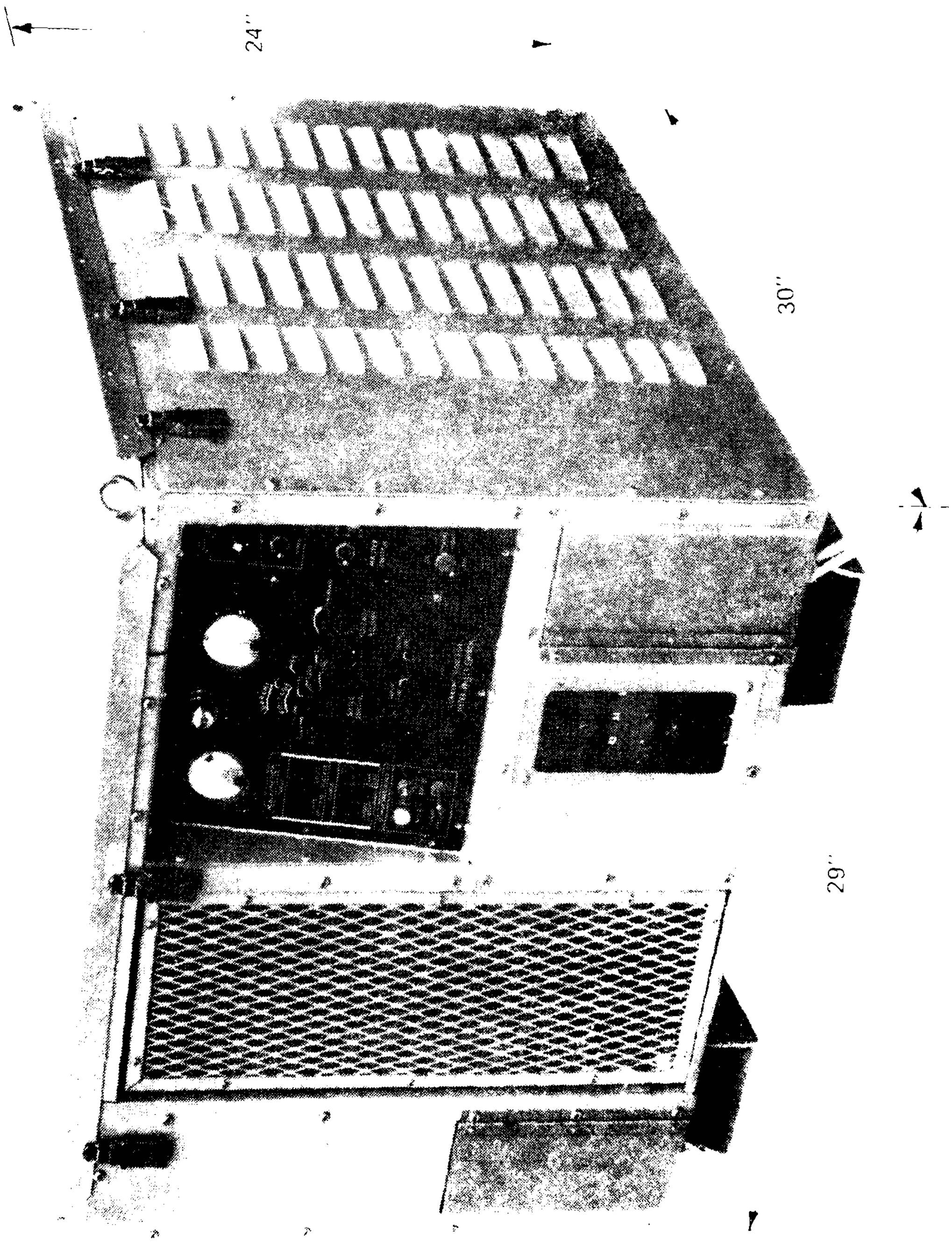


Figure 14. 15 kW Frequency Changer

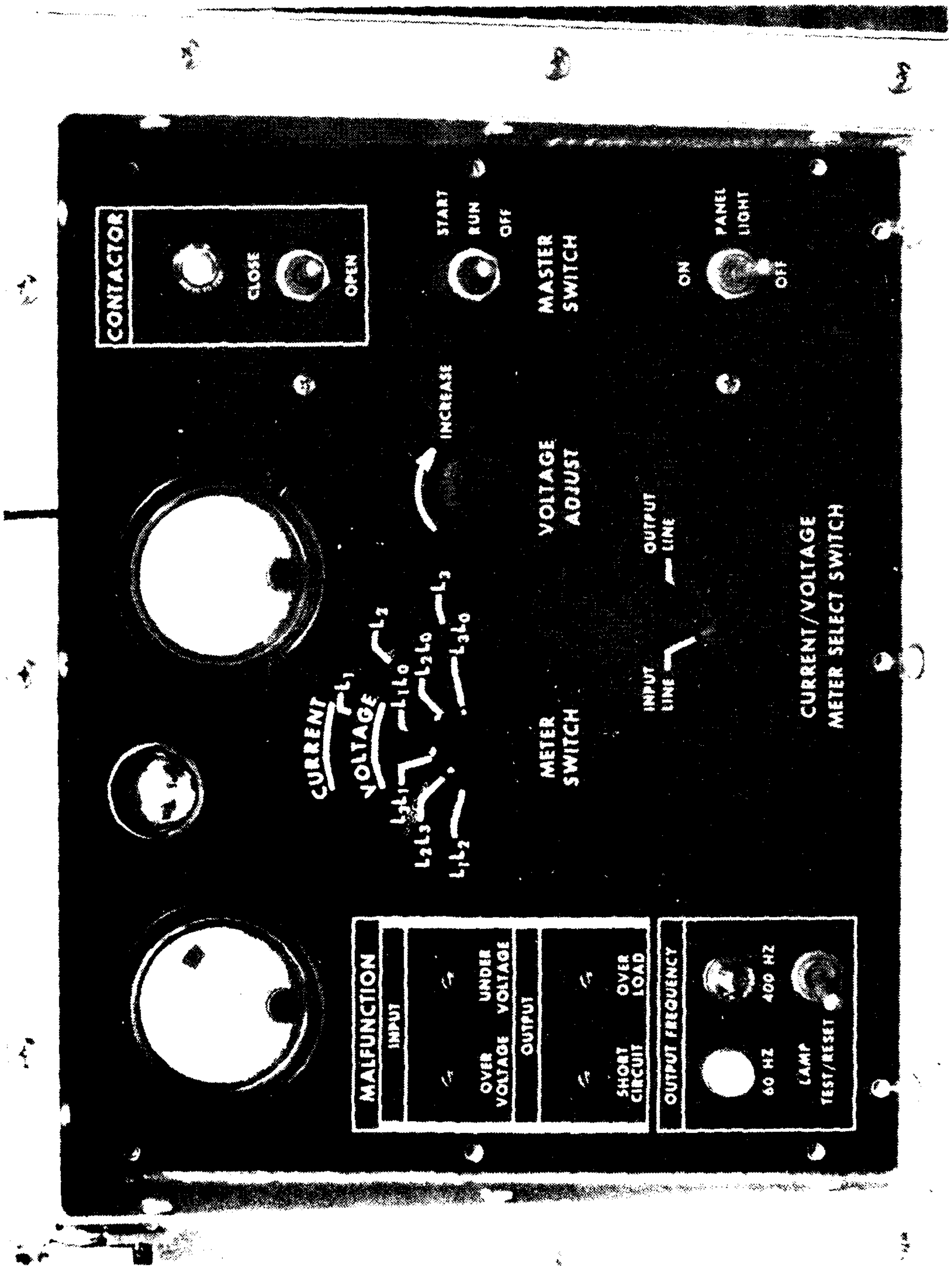


Figure 15. Control Panel

SECTION IV
SUMMARY OF TEST PERFORMANCE

4.1 SUMMARY

The results of the frequency changer electrical performance and endurance tests are summarized in Tables I and II. For some performance characteristics, specifications are not provided explicitly in the purchase descriptions referenced in Section I; and comparison with MIL-STD-1332 Precise or Utility Classes of power is suggested. For a few characteristics there are no specifications at all, and results are simply tabulated and called adequate.

Regulation, losses, efficiencies, and THD are plotted against frequency changer output load in Figures 16 through 25. The recent test data is identical to that previously reported in Delco Electronics Test Report R78-28, and the same summary data applies.

The 1,200-hour endurance test was free of reportable failures. Table II summarizes the test load profile used.

INPUT CHARACTERISTIC PARAMETER	MIL-STD-1332 PRECISE (CLASS 1)	MIL-STD-1332 UTILITY (CLASS 2)	PURCHASE DESCRIPTION	MEASURED PERFORMANCE	COMMENTS OTHER
1) Frequency Changer Input Voltage	N/A	N/A	120/208V +10%, -15%	120/208V +10%, -15%	Complies
2) Frequency Changer Input Frequency	N/A	N/A	50, 60, 400 Hz	60 Hz was tested	Not limited by design
3) Frequency Changer Input Current (60 Hz input frequency) — THD	N/A	N/A	5% over normal load range	5.8% at RL only	Limited (See Note A)
3) — Worse Single Harmonic	N/A	N/A	2% over normal load range	4.2%, 7th harmonic, RL only	Limited (See Note A)
3) — Deviation Factor	N/A	N/A	5% over normal load range	Not tested	See Note A
3) — Peak inrush on application of rated load from no load	N/A	N/A	Not specified	105% of rated load input current <125ms rec. time	Adequate, but PD does not specify
4) Frequency Changer Input Power Factor (60 Hz input frequency)	N/A	N/A	Not specified	Unity (<5° leading)	Adequate, but PD does not specify
5) Converter Output Format (same as Inverter Input)	N/A	N/A	±150 Vdc, 60A (nom. at RL)	±150 Vdc, 60A (nom. at RL)	Complies
6) Voltage Regulation 60 Hz 400 Hz	1% 1%	3% N/A	1.5% 1.5%	<0.5% <0.5%	Complies
7) Steady State Stability — Short term (30 sec) 60 Hz 400 Hz	1% 1%	2% N/A	1% 1%	<0.5% <0.5%	Complies
7) — Long term (4 hrs) 60 Hz 400 Hz	2% 2%	4% N/A	1% 1%	<0.5% <0.5%	Complies
8) Transient Performance — Application of rated load, dip 60 Hz 400 Hz	15%/0.5 sec 12%/0.5 sec	20%/3 sec N/A	20%/2 sec 20%/2 sec	13.7%/250 ms 12.3%/250 ms	Complies
8) — Rejection of rated load, rise 60 Hz 400 Hz	15%/0.5 sec 12%/0.5 sec	20%/3 sec N/A	20%/2 sec 20%/2 sec	14.3%/250 ms 15.0%/250 ms	Complies
8) — Dip for low power factor load 60 Hz 400 Hz	30%/0.7 sec 25%/0.7 sec	40%/5 sec N/A	40%/5 sec 40%/5 sec	1.3%/100 ms 78A/-.5 PF Not measured	Complies
9) Waveform — Total Harmonic Distortion 60 Hz 400 Hz	5% 5%	5% N/A	5% 5%	2.41% 2.64%	Complies
9) — Max Individual Harmonic 60 Hz 400 Hz	2% 2%	2% N/A	2% 2%	1.3%/5th 2.0%/5th	Complies
9) — Deviation Factor 60 Hz 400 Hz	5% 5%	5% N/A	5% 5%	<5% <5%	Complies
9) — Voltage Modulation (or ripple) 60 Hz 400 Hz	- -	- N/A	3V pk-pk (L-N) 3V pk-pk (L-N)	None None	Complies
10) Voltage Unbalance with Unbalanced Load 60 Hz 400 Hz	5% 5%	5% N/A	5% 5%	<1.5% <3.0%	Complies
11) Phase Balance Voltage 60 Hz 400 Hz	1% 1%	1% N/A	Not specified Not specified	<1% <1%	Complies with 1332 Precise

9) Waveform	[illegible] Harmonic Distortion	60 Hz 400 Hz	5% 5%	5% N/A	5% 5%	[illegible] 2.64%	Complies
	Max Individual Harmonic	60 Hz 400 Hz	2% 2%	2% N A	2% 2%	1.3%/5th 2.0%/5th	Complies
	Deviation Factor	60 Hz 400 Hz	5% 5%	5% N/A	5% 5%	<5% <5%	Complies
	Voltage Modulation (or ripple)	60 Hz 400 Hz	- -	- N/A	3V pk-pk (L-N) 3V pk-pk (L-N)	None None	Complies
10) Voltage Unbalance with Unbalanced Load		60 Hz 400 Hz	5% 5%	5% N/A	5% 5%	<1.5% <3.0%	Complies
11) Phase Balance Voltage		60 Hz 400 Hz	1% 1%	1% N/A	Not specified Not specified	<1% <1%	Complies with 1332 Precise
12) Voltage Adjustment Range		60 Hz 400 Hz	-5, +15% -5, +10%	-5, +15% N/A	±5% ±5%	Not tested Not tested	Not limited by design (should be -5, +15%)
13) Short Circuit Current		60 Hz 400 Hz	- -	- N/A	2 PU rated 2 PU rated	2.0 PU 2.0 PU	Control problem (see Note B)
14) All Output Frequency Parameters		60 Hz 400 Hz	- -	- N/A	60 Hz 400 Hz	59.998 Hz 399.99 Hz	Crystal reference complies
15) Phase Angle Balance		60 Hz 400 Hz	- -	- N/A	Not specified Not specified	<1 degree <1 degree	Adequate, but PD does not specify
16) Frequency Changer No Load Losses		60 Hz 400 Hz	N A N/A	N A N/A	500 watts 500 watts	1950 watts 2718 watts	Does not comply
17) Frequency Changer Efficiency at Full Load (1.0 PF)		60 Hz 400 Hz	N/A N/A	N/A N/A	80% 80%	77% 73.3%	Does not comply
18) Frequency Changer Efficiency at Rated Load (0.8 PF)		60 Hz 400 Hz	N/A N A	N A N/A	80% 80%	80.0% 75.8%	Does not comply

NOTES:

A: THD with the frequency changer delivering rated load at 60 Hz or 400 Hz is < 5.8%. If total harmonic content is referenced to the corresponding (i.e., rated) input current THD is nearly the same at lower loads — approximately 6% at no load. The worst single harmonic increases likewise – to approximately 6% at no load.

B: Regulator instability, which can be corrected, was noted.

Table I. Comparison of Electrical Performance With Electrical Specifications

2

SANTA BARBARA, CALIFORNIA

EQUIP FREQUENCY CHANGER

MFGR DELCO

MODEL NO.

SERIAL NO.

REF: MIL-STD-705B 608.1a

TEST NO.

DATE FEB. 3, 1978

BY A. H. BARRETT

TEST REC OUTPUT VOLTAGE REGULATION NL → RL & NL → FL 60HZ

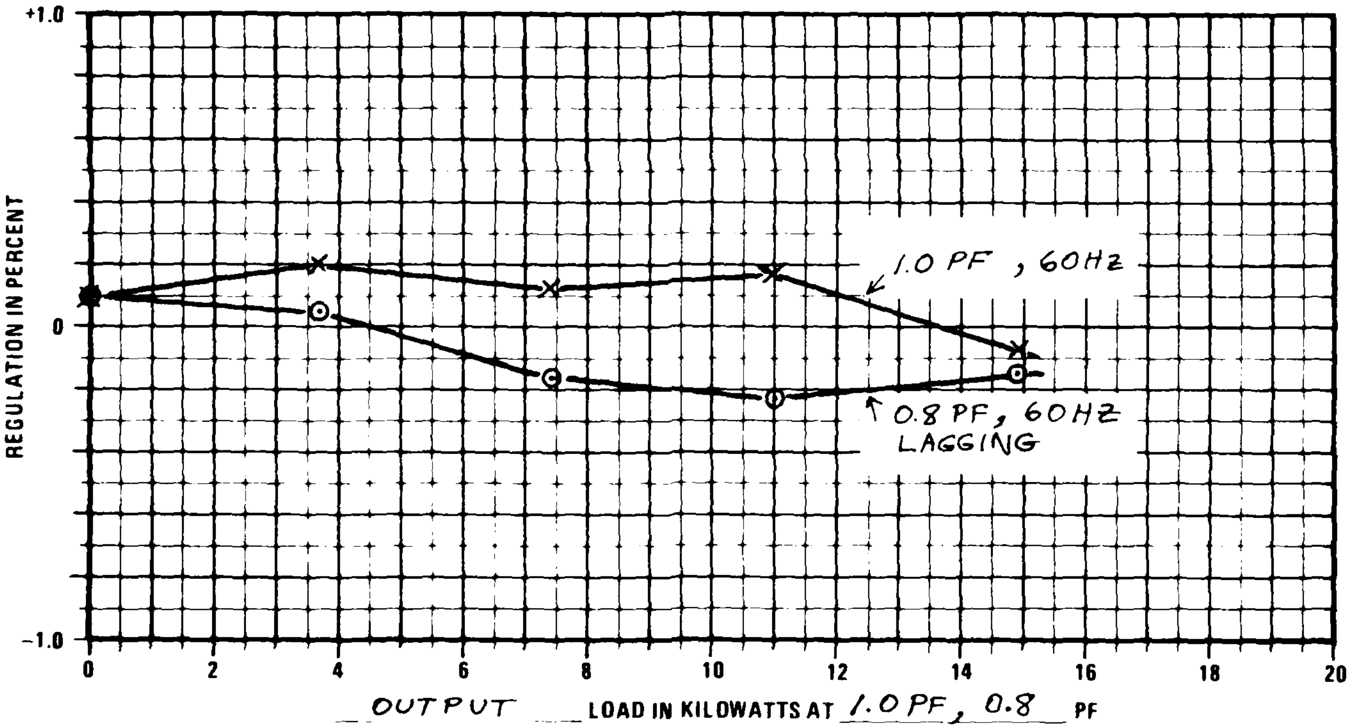


Figure 16. Output Voltage Regulation, 60 Hz

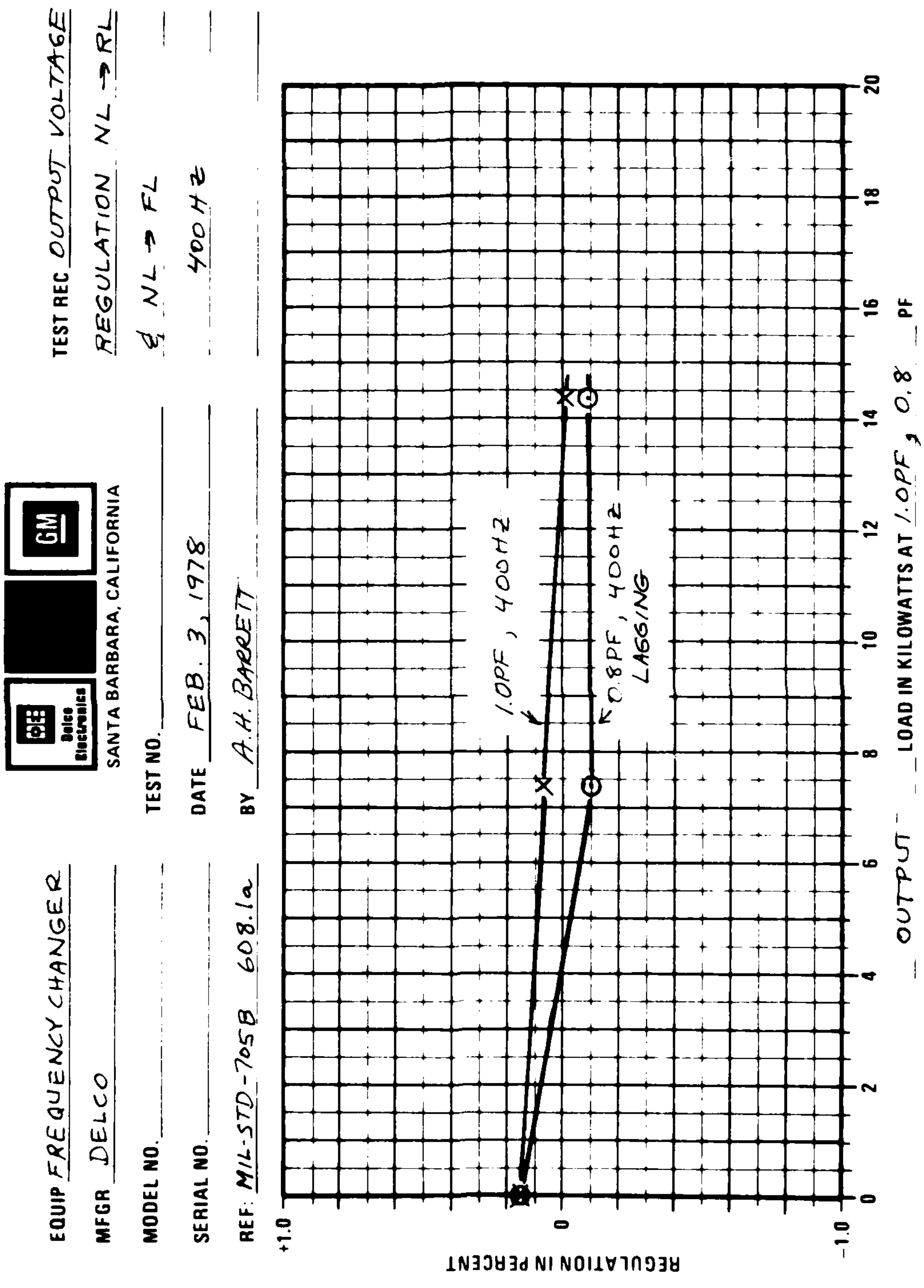


Figure 17. Output Voltage Regulation, 400 Hz

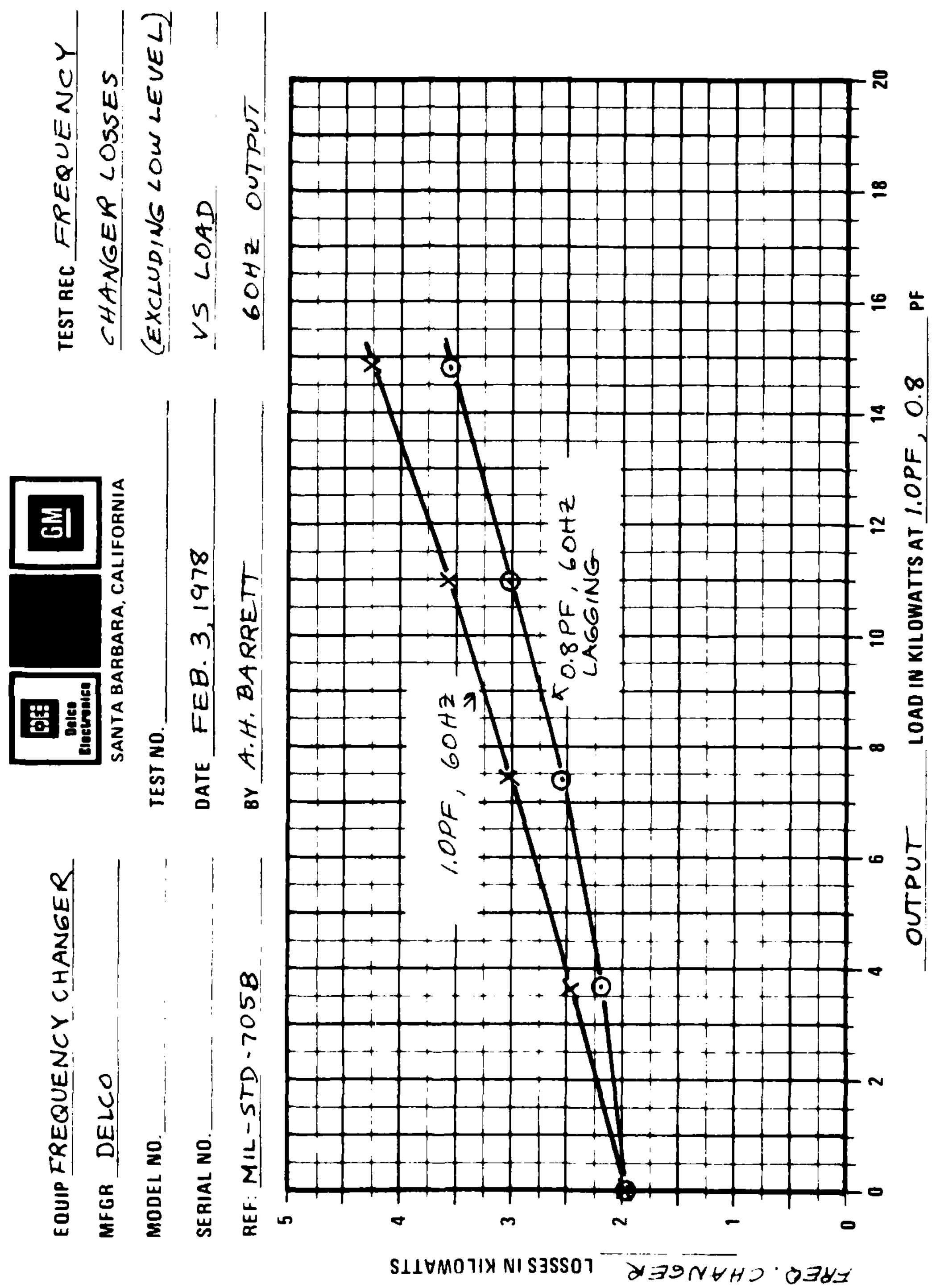


Figure 18. Frequency Changer Losses, 60 Hz Output

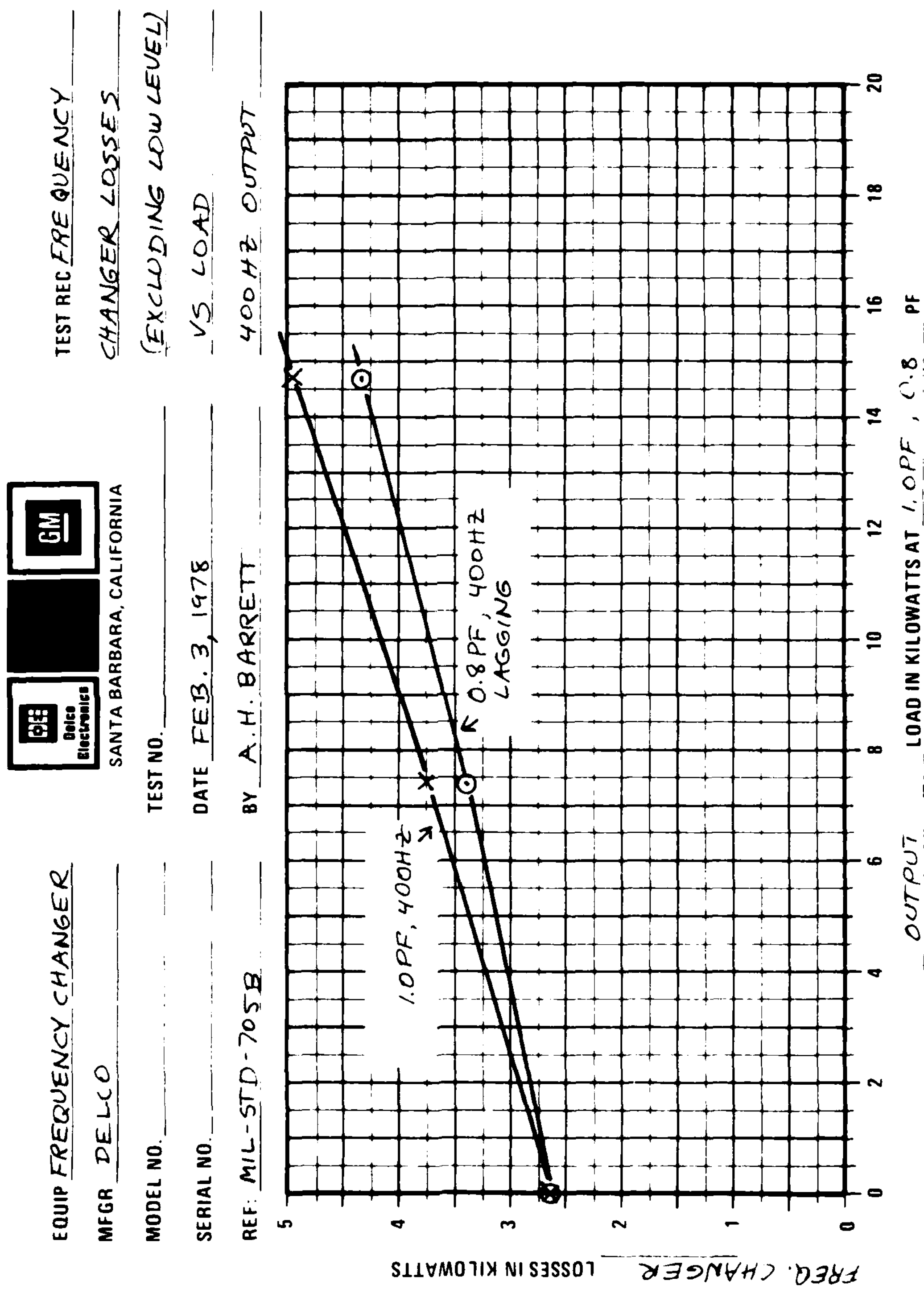


Figure 19. Frequency Changer Losses, 400 Hz Output

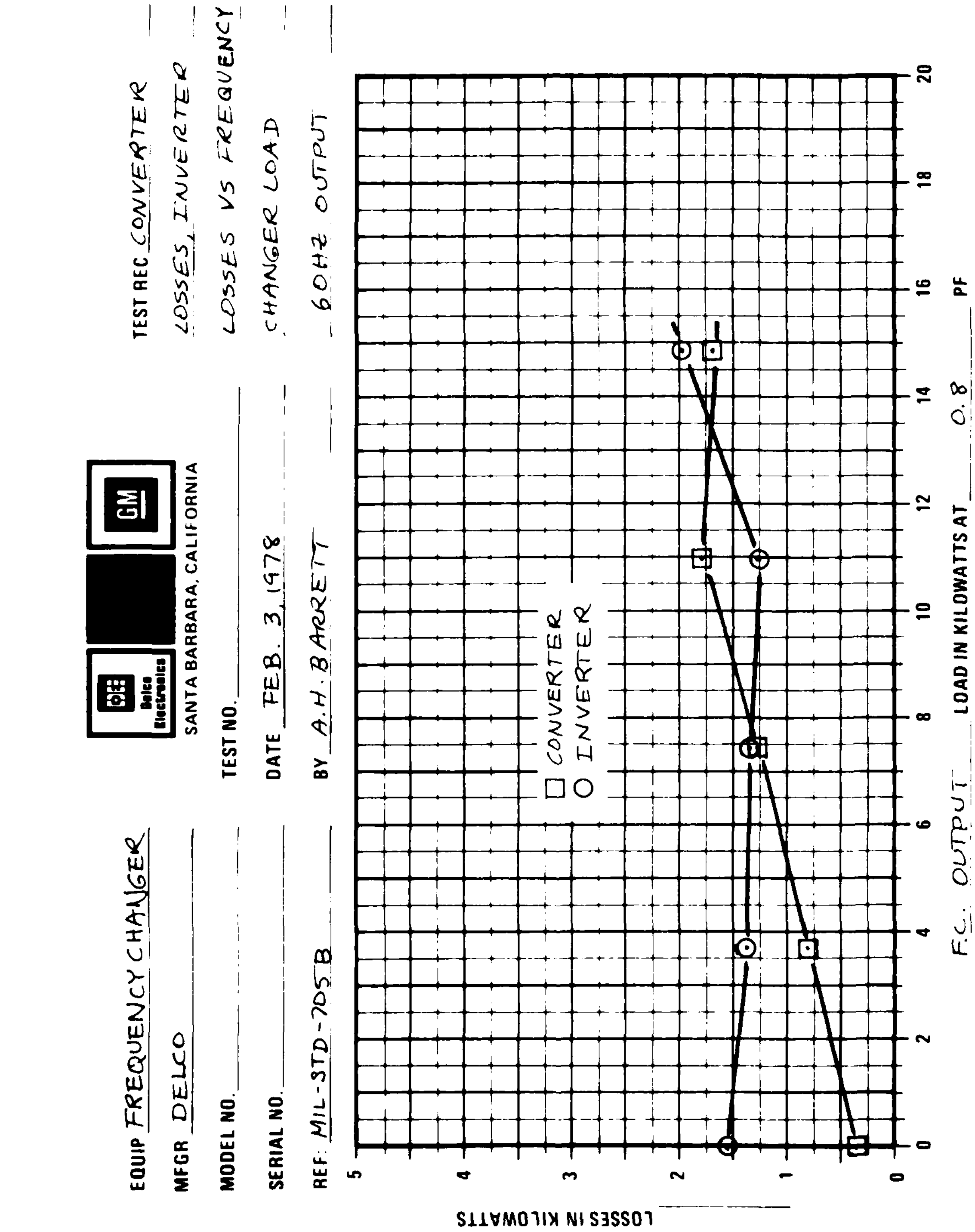


Figure 20. Converter/Inverter Losses vs Load, 60 Hz Output

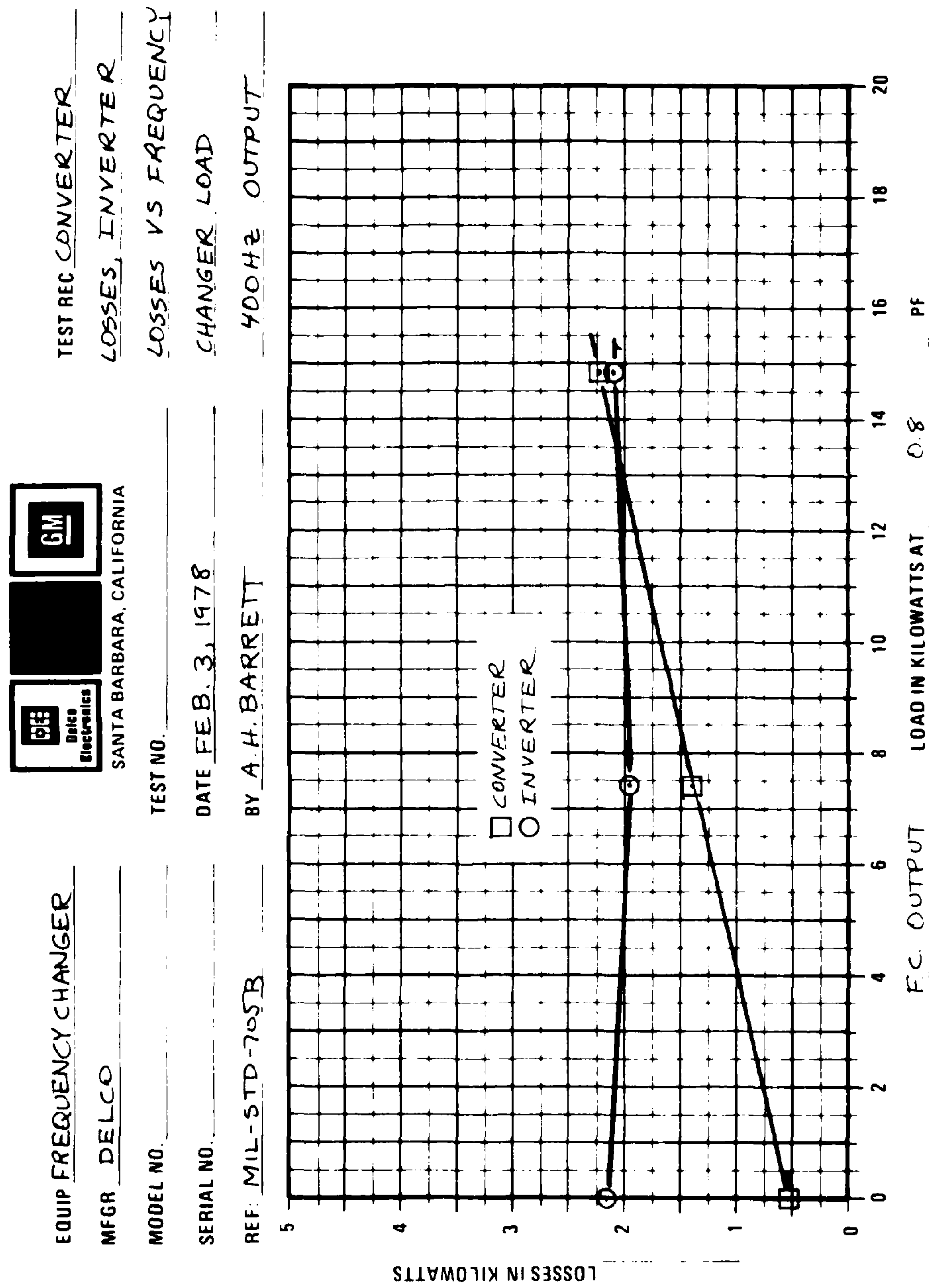


Figure 21. Converter Inverter Losses vs Load, 400 Hz Output

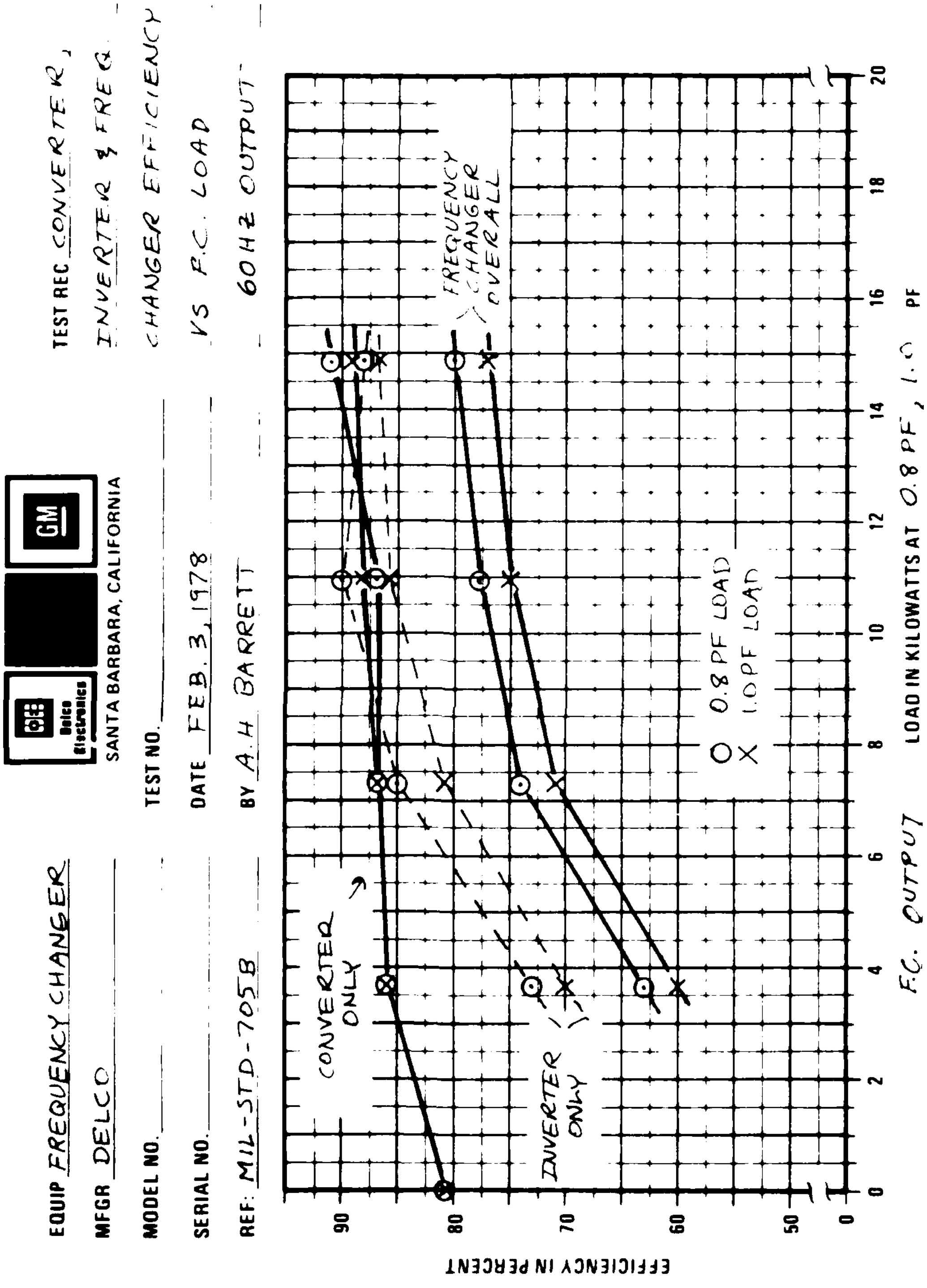


Figure 22. Converter Inverter and Frequency Changer Efficiency, 60 Hz output

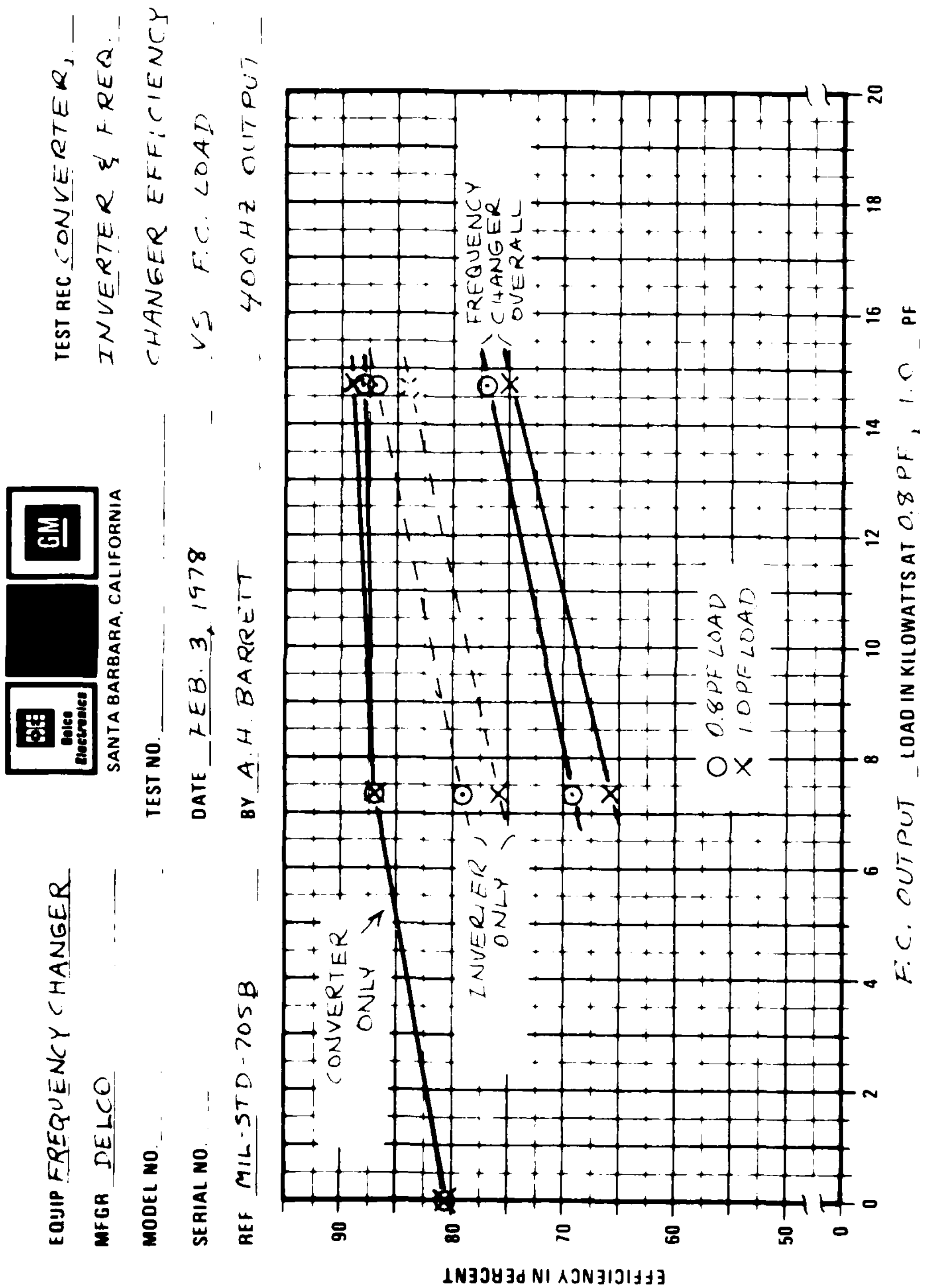


Figure 23. Converter Inverter and Frequency Changer Efficiency, 400 Hz Output

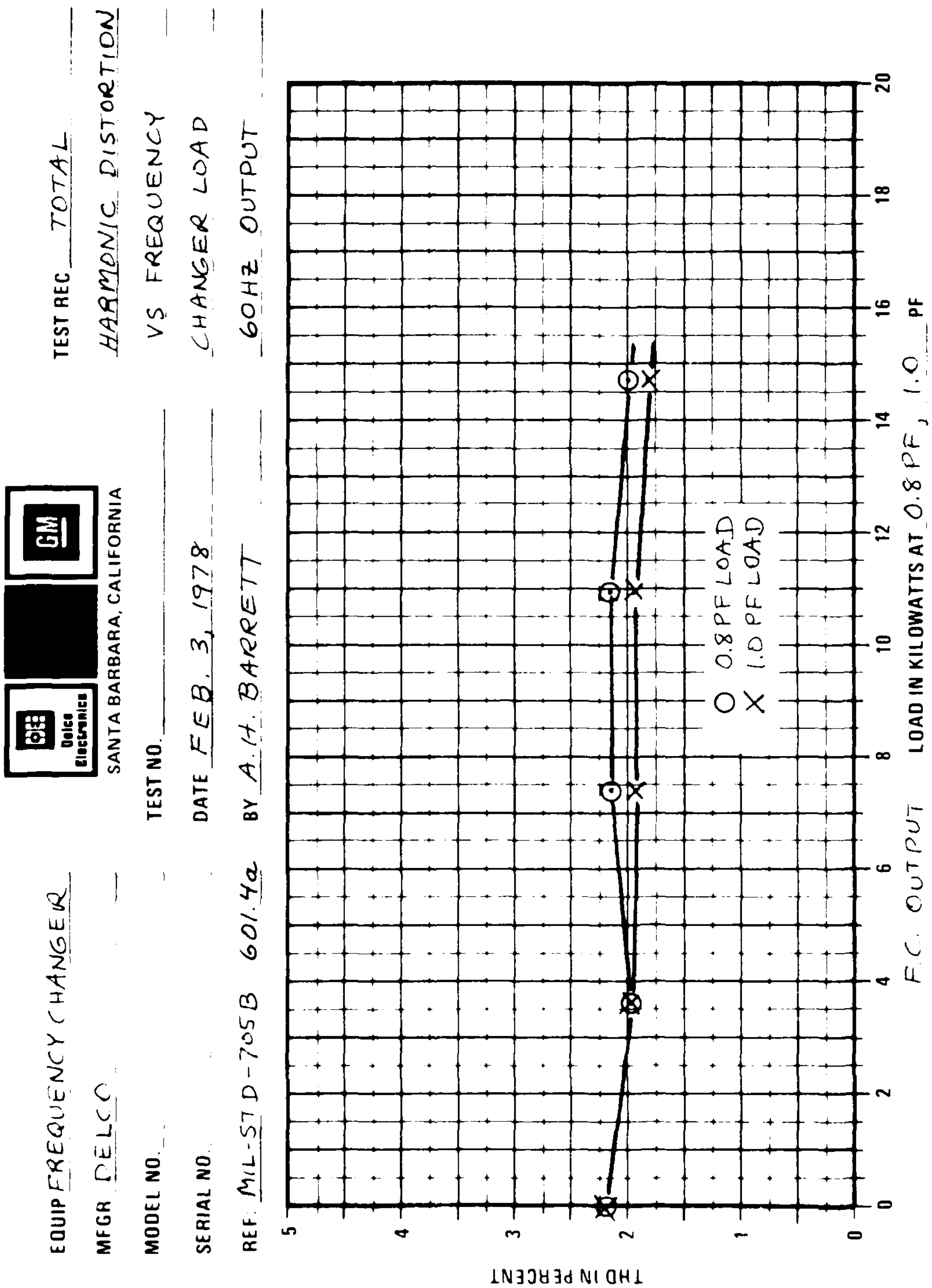


Figure 24. Total Harmonic Distortion versus Load, 60 Hz Output

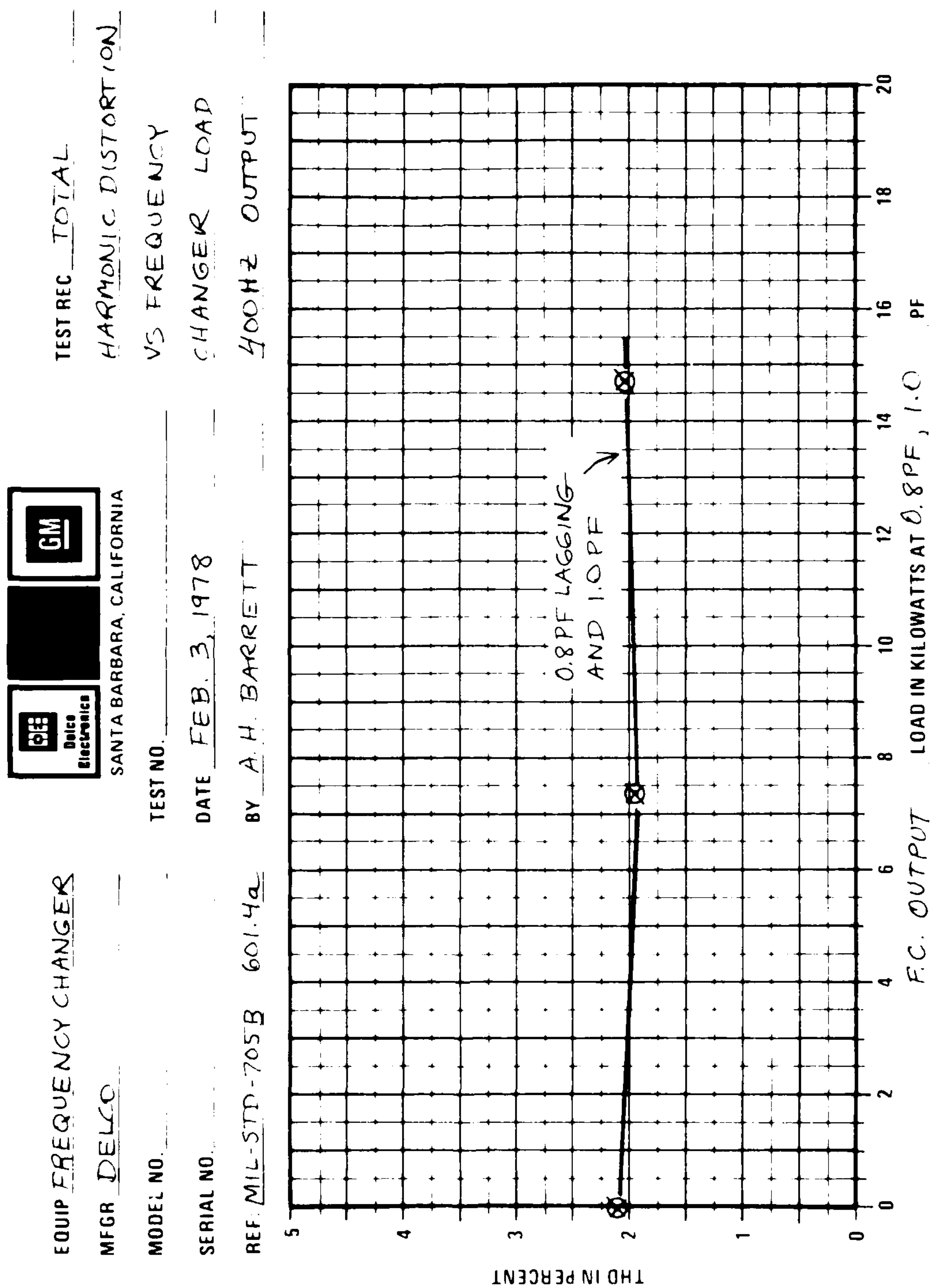


Figure 25. Total Harmonic Distortion versus Load, 400 Hz Output

LOAD	OUTPUT FREQUENCY	
	60 Hz	400 Hz
NL to ≤ 0.25 PU	68 h	1 h
>0.25 PU to ≤ 0.5 PU	300.5 h	143 h
>0.5 PU to ≤ 0.75 PU	185 h	224 h
>0.75 PU to ≤ 1.0 PU	169.5 h	111 h

Total Time 1,202 hours (no failures)

NOTE: PU indicates per unit rated load. Testing was done at 0.8 power factor lagging and unity power factor loading.

Table II. Endurance Test Loads

SECTION V
CONCLUSIONS AND RECOMMENDATIONS

Most test results are better than, or at least compliant with, PD or other requirements. There are deviations, measured or suspected, which are discussed herein.

5.1 PARAMETER 2 — FREQUENCY CHANGER INPUT FREQUENCY AND PARAMETER 3 — INPUT CURRENT

The set was tested only with 60 Hz input power because adequate 50 Hz and 400 Hz power sources are not available at Delco. There is no design limitation which precludes operation at 50 Hz and 400 Hz. It is quite possible that the present converter input filter would not function as is at 400 Hz, but incorporation of a new relay-controlled center tap on the input inductor of Figure 3 would probably prove effective.

Deviation from the ideal sinusoidal input current is above that specified in the PD. Distortion components are considerably above those measured on a breadboard frequency changer and reported in Delco Electronics Test Report R78-28. For example, at rated load, input current THD was reported as 3.5 percent. It is now reported as 5.8 percent.

The reasons for the degradation in performance should be evaluated. It is believed that the staggered firing pattern of the A, B, and C phase converter SCR's, as opposed to the simultaneous firing pattern formerly used, is the main contributor to the degradation. Addition of a logic power supply in the system may also be a contributing factor.

An amendment to the PD specification should be made if necessary after simultaneous firing has again been tried and analyzed.

5.2 PARAMETER 13 — SHORT CIRCUIT CURRENT

Testing of single, two, and three-phase short circuits (from RL) was done only at 60 Hz output frequency. Earlier testing indicated similar results at 400 Hz output frequency. The inverter portion always seems to function well, but a problem exists in the converter control.

As previously reported, there is still an instability in the low level control circuit for the converter. This results in bursts of output approximately 0.5-second long spaced by "no output" periods of approximately 0.25 second. However, a balanced three-phase short circuit does not cause control instability, and approximately 110A rms per phase was recorded. It has been concluded that accurate and instantaneous monitoring of inverter input current is required for proper short circuit control. This circuit augmentation should be made to the set.

5.3 PARAMETER 16 — NO LOAD LOSSES, PARAMETER 17 — EFFICIENCY AT FULL LOAD, PARAMETER 18 — EFFICIENCY AT RATED LOAD

The purchase description (Ref Section I) states that the no load loss shall not exceed 500 watts and that efficiency with the set operating above 25 percent of rated power shall be 80 percent minimum. No-load losses are well in excess of those specified and, in the fully packaged frequency changes, they are 2.8 kW. The rated load efficiency is 80 percent at 60 Hz output and 76 percent at 400 Hz output.

5.4 RECOMMENDATIONS

Harmonic distortion of the input currents to the frequency changer is very low, although it is greater in some cases than that specified. The input filter for the converter certainly can be improved upon. More should be learned about the effects of source impedance on input current harmonics. It is recommended that Delco refine the input filter while studying source impedance effects. MERADCOM should consider changing the current harmonic specifications. It is recommended that Navy specifications for frequency changers, from the NAVSEC offices, be reviewed.

Delco should further refine the low level control circuits so as to eliminate instabilities that have been shown to occur with heavy unbalanced loads and short circuits.

It was observed during severe overload testing that in addition to output current limiting problems, there were power limiting problems. The frequency changer has no control input to provide constant power into an overload. It is strongly recommended that a constant power limit mode of operation be added.

At 821 hours into the endurance test, a brownout occurred on the 60 Hz input to the frequency changer. The brownout was properly sensed as undervoltage (7 cycles at 80 V), and the set was shut down. A brownout at 1,172 hours caused a second shutdown. The question of what action the set should take in the event of a brownout needs to be answered.

Rather high no-load and light-load losses are related to the specific inverter approach used. The two major contributions are from the following:

- Load-independent, high level, forced commutation circuits
- A very large, fixed, leading power factor, output filter.

It is not recommended that any changes be made in the commutation circuitry, which accounts for at most, a few hundred watts of loss at 400 Hz. It is recommended that consideration be given both by MERADCOM and Delco to implementation of an incrementally variable output filter. The present filter draws 1.1 PU rated output current at 0 PF, leading. This is responsible for as much as 2 kW loss at no load. At no-load and light-loads, smaller filters would greatly reduce inverter losses and, consequently, converter losses and improve loaded efficiency. At rated load, Delco should evaluate the use of a 0.9 to 1.0 PU output filter to slightly improve rated load efficiency.

Temperature checks made on the fully enclosed frequency changer showed several areas of excessive temperature rise. Although some improvement was made by providing more air flow to these areas, they are still too hot for safe operation at 125°F ambient air. It is strongly recommended that thorough temperature tests be made and that redesign efforts be directed to reduction of temperature rise in areas where problems are found to exist.

APPENDIX

Parts Lists and Diagrams

DWG NO. SK002313 REV —

REVISIONS

LTR	DESCRIPTION	AUTH.	DATE	APPD

REVISION	—	—	—	—																								
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR Mastusak	24 OCT 78	**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR [signature]	19 Oct 78	TERMINATION & FILTER ASSY
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK002313 · REV —
CONTR NO.	OTHER APPD		SCALE — · WEIGHT · SHEET 1 OF 4

drl- 382 (rev 4-71)

CLASS ____.

DELCO ELECTRONICS DIVISION • SANTA BARBARA OPERATIONS • GENERAL MOTORS CORPORATION

PARTS LIST

CONTRACT NO.:

CODE IDENT NO.: 13160 — SK002313

REV LTR: -

LIST TITLE: TERMINATION & FILTER ASSY

AUTHENTICATION:

REVISION NOTICE NO:

REV DATE:

ITEM NO.	QTY REQD	QTY REQD	QTY REQD -021	QTY REQD -011	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1			—	1		98376	SK002313-006		HOUSING MAKE FROM ET66-108A	
2			1	-		98376	SK002313-007		HOUSING MAKE FROM ET66-108A	
3			—	1			SK002313-001		BOARD, MOUNTING	
4			1	-			-002		BOARD, MOUNTING	
5			1	1			-003		BRACKET MTG, LEFT	
6			1	1			-004		BRACKET MTG, RIGHT	
7			4	4			-005		BAR, BUSS	
8			6	6			MS21076L06		NUT PLATE	[illegible]
9			12	12			MS20470AD3-6		RIVET, 100°	[illegible]
10			6	6			MS20470AD3-3		RIVET, 100°	[illegible]
11			4	4		82168	DGM6-2		TERMINAL	
12			4	4		56289	JN17-5115A		FILTER, 100A	
13			6	6			6-32 X 1/2 LG		SCREW, PAN HD	

PARTS LIST

CONTRACT NO	CODE IDENT NO. 13160	SK002313		REV LTR —
LIST TITLE: TERMINATION & FILTER ASSY	AUTHENTICATION	REVISION NOTICE NO	REV DATE	SHEET 4 OF

ITEM NO.	QTY REQD	QTY REQD	QTY REQD -021	QTY REQD -011	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
14			8	8			10-32 X 5/8 LG		SCREW, FLAT HD 100°	
15			8	8			10-32		NUT, HEX	

REV A

DWG NO. SK002363

REVISIONS				
LTR	DESCRIPTION	AUTH.	DATE	APPD
A	P/L CHG	G.H.B.	9-2-80	

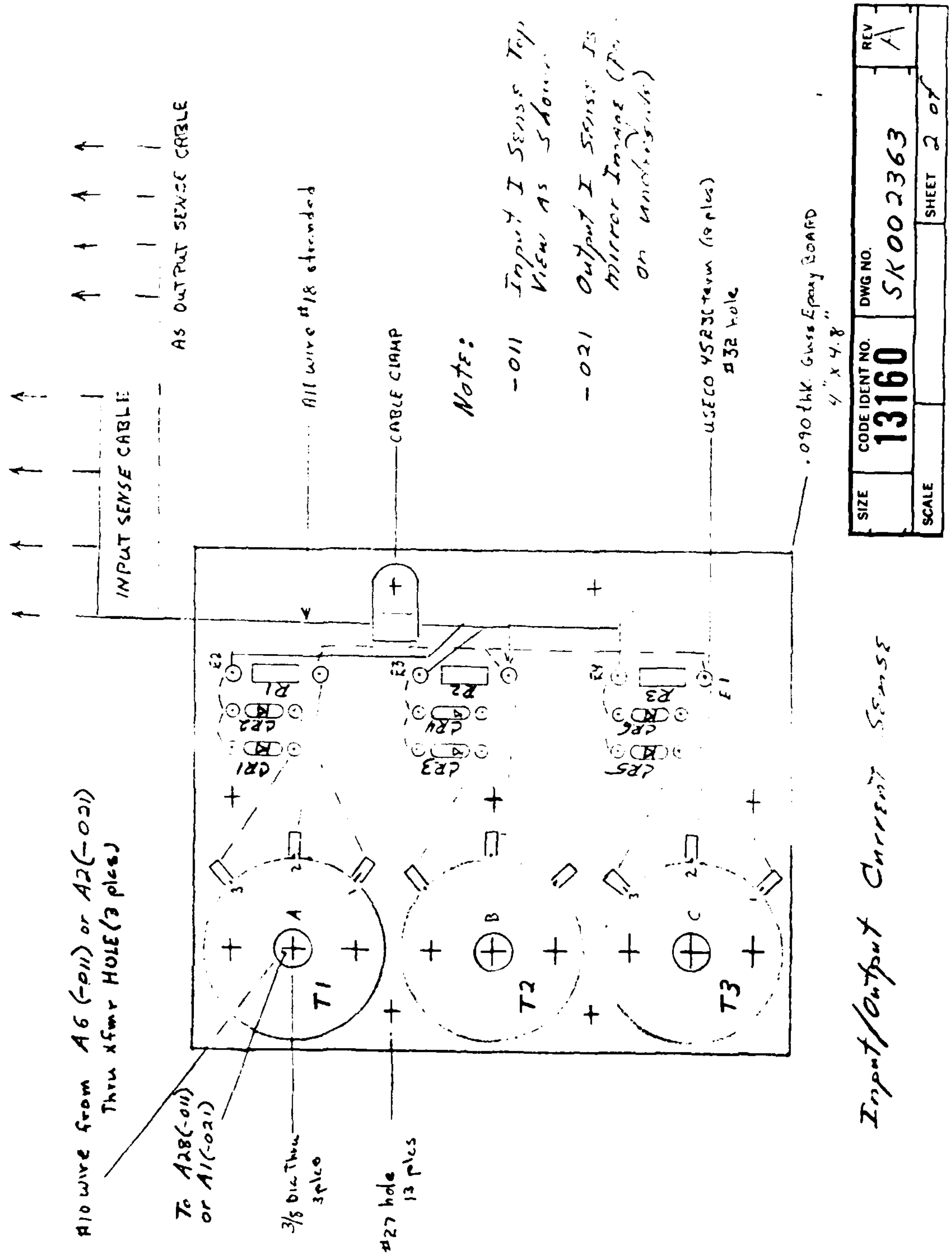
REVISION	A	A	A																									
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR RFB	5/31/79	INPUT/OUTPUT CURRENT SENSE A25(-011) & A26(-021)
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A — CODE IDENT NO. 13160 — DWG NO. SK002363 — REV A
CONTR NO.	OTHER APPD		SCALE — WEIGHT — SHEET 1 OF 3

drl-382 rev 4-71)

CLASS ____.


INPUT SENSE CABLE
AS OUTPUT SENSE CABLE
All wire #18 stranded
CABLE CLAMP
Note:
-011 Input I Sense Top View As Shown
-021 Output I Sense Is Mirror Image
USECO 4523C term (9 plcs) #32 hole
.090 thk Glass Epoxy BOARD 4" x 4.8"
#10 wire from A6(-011) or A2(-021) Thru Xfmr HOLE (3 plcs)
To A28(-011) or A1(-021)
3/8 Dia Thru 3 plcs
#27 hole 13 plcs
R1
R2
R3
CR1
CR2
CR3
CR4
CR5
CR6
E1
E2
E3
E4
T1
T2
T3
Input/Output Current Sense
SIZE
CODE IDENT NO. 13160
DWG NO. SK002363
REV A
SCALE
SHEET 2 of

PARTS LIST

CONTRACT NO.	CODE IDENT NO.		REV LTR
	13160	SK[illegible]	[illegible]

LIST TITLE: Input/Output Current Sense A25 & A26

AUTHENTICATION	REVISION NOTICE NO	REV DATE	SHEET OF

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	P. NOTES
1	6						JAN 1N4448		Silicon Rectifier CR1-CR6	
2	3						RNC70H24R9FM		Resistor, 24.9Ω, 1% 0.5W, R1, 2 & 3	
3	3						80A300		Transformer (Delco) T1, 2 & 3	
4	1						MS 25281		Clamp	
5	18						4523[illegible]		Turret Terminal (Uss [illegible])	
6	1								Epoxy Board 4" x 4.8" x .070"	
7	1						SK002427		Reference Schematic (Delco)	

DWG NO. SK002364 REV A

REVISIONS				
LTR	DESCRIPTION	AUTH.	DATE	APPD
A	P/L CHG.	GHB	9280	

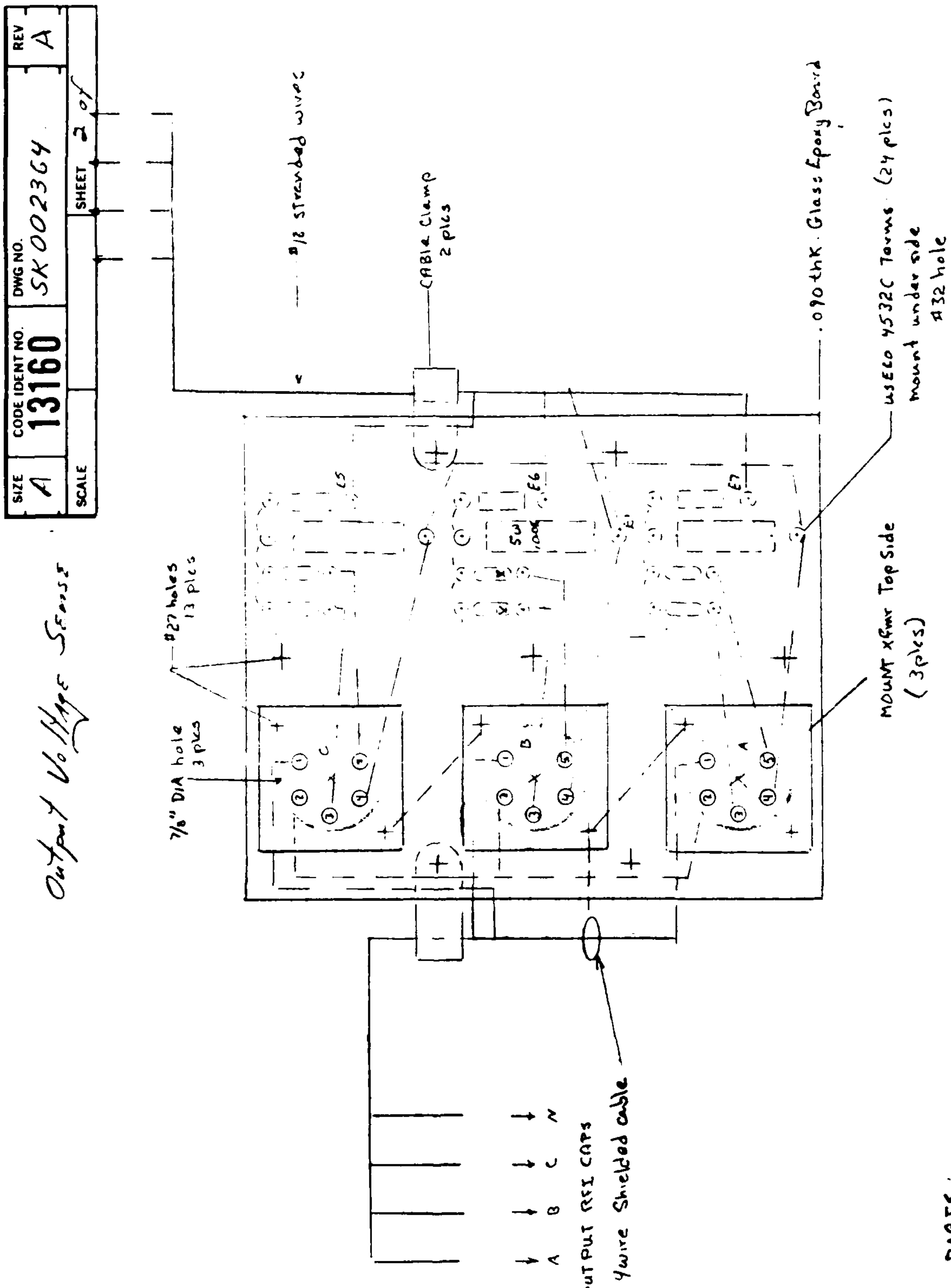
REVISION	A	A	A																									
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR RFB	5/31/79	OUTPUT VOLTAGE SENSE A27
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK002364 · REV A
CONTR NO.	OTHER APPD		SCALE · WEIGHT · SHEET 1 OF 3

drl-382 (rev 4-71)

CLASS


SIZE A
CODE IDENT NO. 13160
DWG NO. SK002364
REV A
SCALE
SHEET 2 of
Output Voltage Sense
#12 Stranded wires
CABle Clamp 2 plcs
.090 thK. Glass Epoxy Board
USECO 4532C Terms (24 plcs) mount under side #32 hole
MOUNT Xfmr Top Side (3 plcs)
#27 holes 13 plcs
7/8" DIA hole 3 plcs
E5
E6
E7
A
B
C
N
UTPUT RFI CAPS
4wire Shielded cable
PARTS

PARTS LIST

CONTRACT NO:
CODE IDENT NO: 13160 — SIS 7364
LIST TITLE: Output Voltage Sense 420
AUTHENTICATION:
REVISION NOTICE NO:
REV DATE:

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1	6						JAN 1N5619		Silicon Rectifier CR1-CR6	
2	3						RWR?4S1002FM		Resistor, R2, 4 & 6 10.0KΩ, 5W	
3	3						RNC60H2002FM		Resistor, R1, 3 & 5 20.0K, 0.25W, 1%	
4	2						MS 25281		Clamp	
5	3						TF4R?X01AH M8094		Transformer (Microtran) T1, 2 & 3	
6	24						4532C		Turret Terminal (USECO)	
7	1								Epoxy Board 4" x 4.8" x .0??	
8	1						SK002427		Reference Schematic (Delco)	

DWG NO. SK002365 REV +

REVISIONS

LTR	DESCRIPTION	AUTH.	DATE	APPD

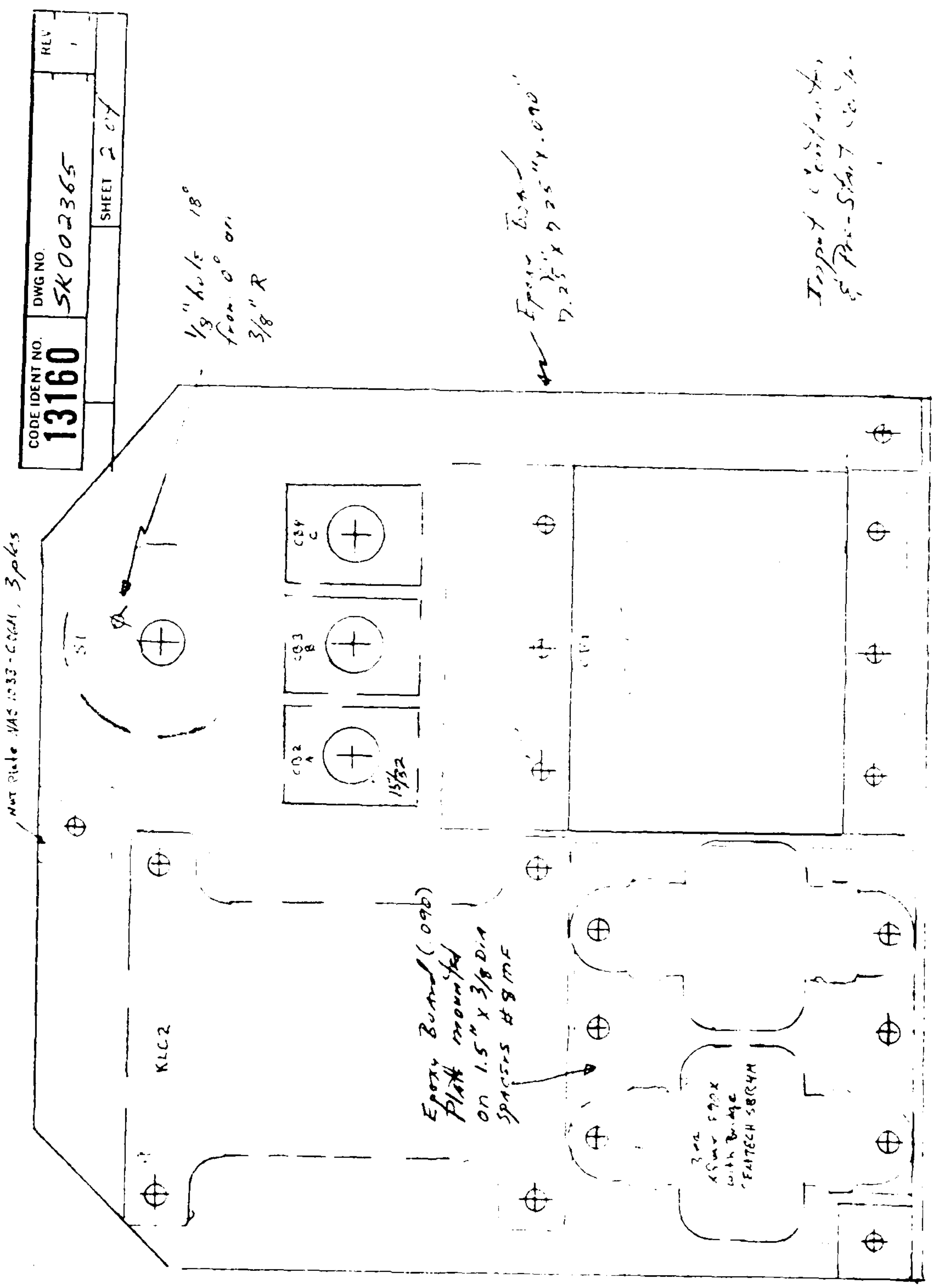
REVISION	+	+	+																									
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR RFB	5/31/–	INPUT CONTACTORS & PRE-START CONTROL A28
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK002365 · REV +
CONTR NO.	OTHER APPD		SCALE · WEIGHT · SHEET 1 OF 3

drl-382 (rev 4-71)

CLASS


CODE IDENT NO.
13160
DWG NO.
SK002365
SHEET 2 OF
REV
KLC2
S1

PARTS LIST		CONTRACT NO.	CODE IDENT NO. 13160	SK002365	REV LTR Y
LIST TITLE INPUT CONTACTORS & Pre-Start Control		AUTHENTICATION	REVISION NOTICE NO	REV DATE	SHEET 3 OF

ITEM NO	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1	1						P3XAM1516		Circuit Breaker 100A, (Heinamann)	CB1
2	3						MS25244-5		Circuit Breaker, 5A, CB2,3 & 4	
3							M39014/01-1225		Capacitor, 0.022μF, 200V, 10%	C1
4	3						SBR4M		Rectifier (Semtech)	CR1,2 & 3
5	1						RCR42G471JS		Resistor, 470Ω 2W	R1
6	2						RCR20G333JS		Resistor, 3.3KΩ 0.5W	R2, 3
7	1						9565H13A		Power Relay (Cutler-Ham.)	KLC2
8	3						F90X		Transformer (Triad)	T1,2 & 3
9	3						NAS1033-CD6M		Nutplate	
10	1						42D36-02-2-AJN		Rotary Switch (Grayhill)	S1
11	1						SK002427		Reference Schematic (Delco)	

REVISIONS

LTR	DESCRIPTION	AUTH.	DATE	APPD

DWG NO. SK002409

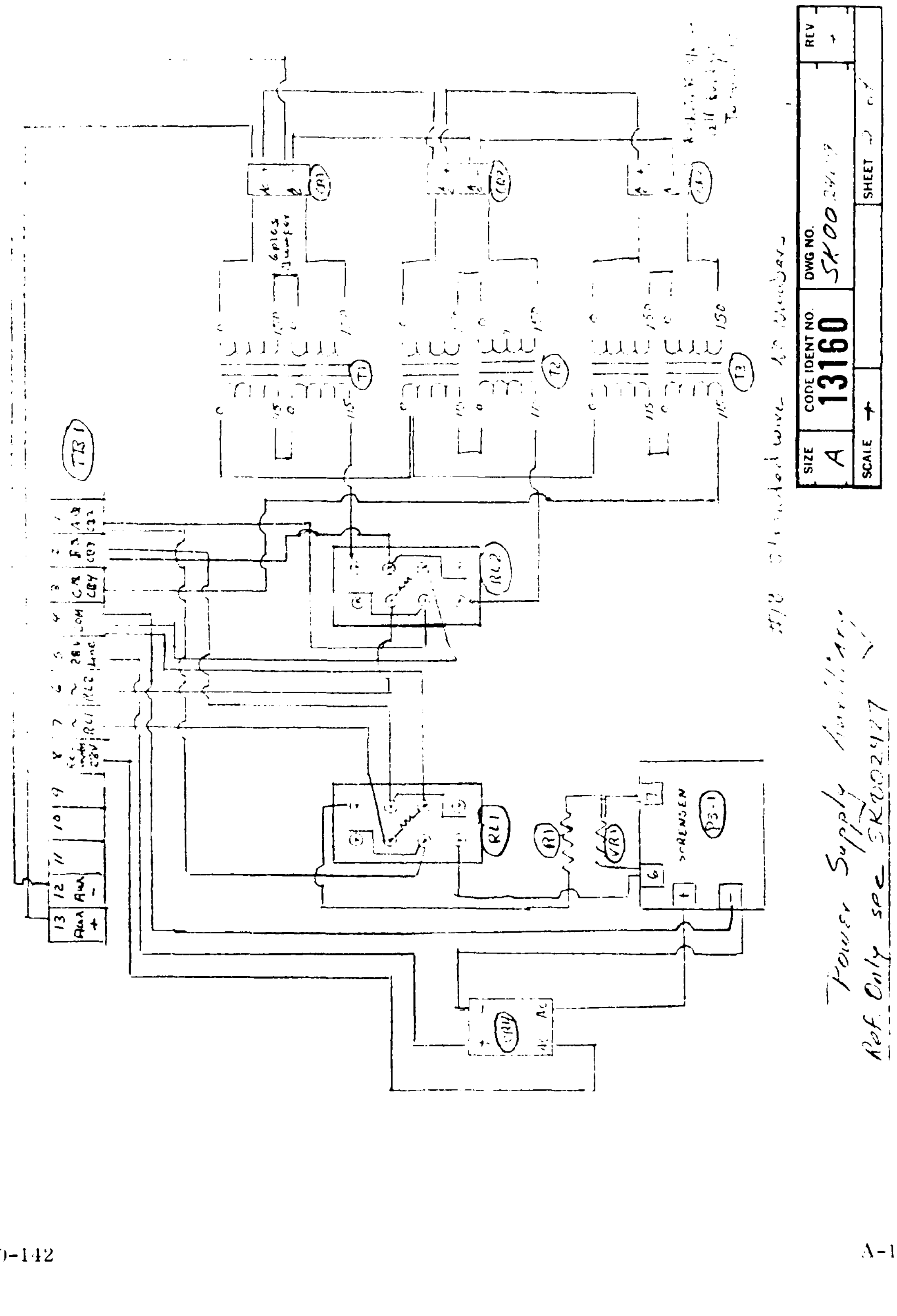
REVISION	+	+	+																									
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF DOG	ENGR RFB	5/31/79	POWER SUPPLY, AUXILIARY -24
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A / CODE IDENT NO. 13160 / DWG NO. SK002409 / REV +
CONTR NO.	OTHER APPD		SCALE / WEIGHT / SHEET 1 OF 3

drl-382 (rev 4-71)

CLASS


SIZE
A
CODE IDENT NO.
13160
DWG NO.
SCALE
SHEET
REV
TB1
RL1
RL2
T1
T2
T3
SORENSEN

PARTS LIST

LIST TITLE	CONTRACT NO	CODE IDENT NO		AUTHENTICATION	REVISION NOTICE NO	REV DATE
Power Supply, Auxiliary A24		13160	SK002402			

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE
1	4						SCBA6F		Rectifier Bridge (Semtech) CR1 - CR4	
2	1						SSD24-8.5		Power Supply (Semtech) PS [illegible]	
3	2						CA 800-8, BR17X-300D2-26V		Relay (Babcock), RL1, 2	
4	1						NH-50, 4.99Ω, 30W		Resistor (Dale) R1	
5	1						V250HE250		MOV (GE), VR1	
6	3						DL-300-0.5		Transformer (Signal) T1 - [illegible]	
7	1						MS27212-2-13		Terminal Block 13 No. 10 Studs TB1	
8	1						SK002315		Bracket (Delco)	
9	2						SK002316		Side Plate (Delco)	
10	1						SK002427		Reference Schematic (Delco)	

DWG NO. SK002405

REVISIONS				
LTR	DESCRIPTION	AUTH.	DATE	APPD
A	REVS'D SCHEMATIC & RELEASE		9-17-80	

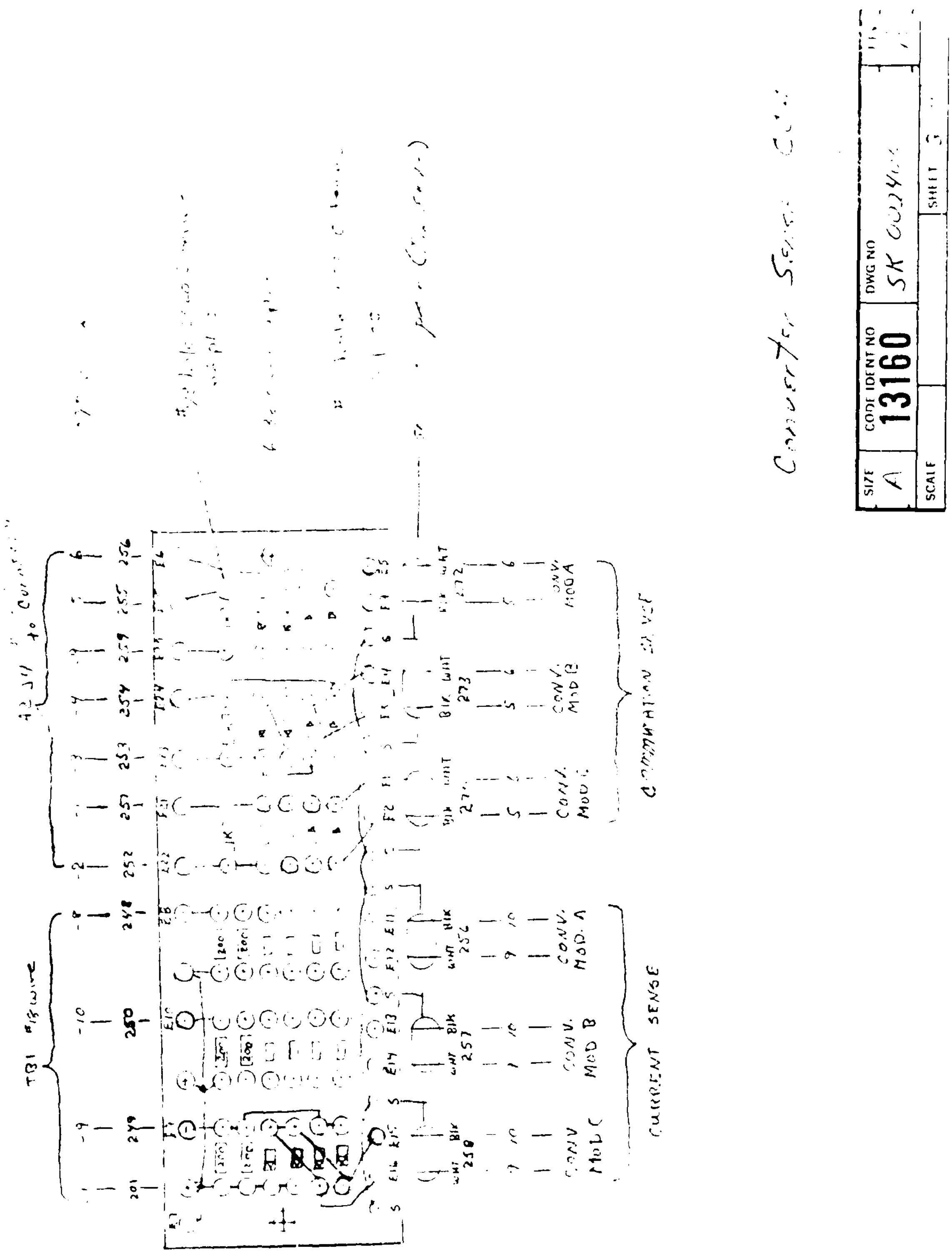
REVISION	A	A	A	A																								
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR RFB	5/31/79	CONVERTER SENSE CCA A20
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A / CODE IDENT NO 13160 / DWG NO. SK002405 / REV A
CONTR NO.	OTHER APPD		SCALE / WEIGHT / SHEET 1 OF 4

drl-382 (rev 4-71)

CLASS


SIZE
A
CODE IDENT NO
13160
DWG NO
SCALE
SHEET
TB1
CURRENT SENSE
CONV. MOD A
CONV. MOD B
CONV MOD C

PARTS LIST

LIST TITLE CCA Converter S[illegible]

ITEM NO	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION
1	24						JAN 1N4148-1		S[illegible] [illegible] CR[illegible]
2	3						RCR20102JS		1K ±5% 0.5W [illegible] R[illegible]-R[illegible]
3	6						RNC60H2000FM		200 ±1%, 0.25W [illegible]
4	66						2520-C		T[illegible]
5	33						453[illegible] C		[illegible]
6	1								[illegible], 2[illegible]

DELCO ELECTRONICS DIVISION • SANTA BARBARA OPERATIONS • GENERAL MOTORS CORPORATION

REV A

DWG NO.

REVISIONS

LTR	DESCRIPTION	AUTH.	DATE	APPD
A	REVISED SCHEMATIC & RELEASE		9-17-80	W.T.

REVISION	A	A	A	A																								
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR [illegible]	[illegible]	START-UP & PROTECTION No 1 A [illegible]
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK [illegible] · REV A
CONTR NO.	OTHER APPD		SCALE · WEIGHT · SHEET 1 OF 4

drl-382 (rev 4-71)

CLASS

PARTS LIST

CONTRACT NO	CODE IDENT NO		REV LTR	SHEET
	13160	[illegible]24[illegible]	[illegible]	[illegible]

LIST TITLE: Start-Up & Protection No 1 A 31

AUTHENTICATION	REVISION NOTICE NO	REV DATE

ITEM NO	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1	1						M39003/01-2355		Capacitor, 1.2 µF [illegible] V	1
2	1						M39003/01-2275		Capacitor, 47 µF 20 V	[illegible]
3	9						M39014/01-1454	CK05	Capacitor 0.1 µF	
4	2						M39003/01-2306		Capacitor [illegible]	
5	6						M39015/3-[illegible]W[illegible]		Resistor [illegible]	
6	7						RCR0[illegible]103JS		Resistor, [illegible]	
7	2						RCR0[illegible]124JS		Resistor [illegible]	
8	7						RNC55H1003FP		[illegible]	
9	1						RCR0[illegible]G226JS		Resistor [illegible]	1
10	1						RCR0[illegible]125JS		Resistor [illegible]	1
11	1						RCR[illegible]		[illegible]	[illegible]
12	1						RCR[illegible]JS		[illegible]	[illegible]
13	4						[illegible]		[illegible]	[illegible]

PARTS LIST

TITLE: Start-Up [illegible] Protection [illegible]

CODE IDENT NO: 73160

ITEM NO	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	REF NOTES
[illegible]	[illegible]						[illegible]		[illegible]	[illegible]
	[illegible]						[illegible]		I.C.	U2
[illegible]							[illegible]		I.C.	U3
[illegible]	1						[illegible]		I.C.	[illegible]
[illegible]	1						[illegible]		I.C.	[illegible]
[illegible]							[illegible]		I.C.	[illegible]
[illegible]	1						[illegible]		I.C.	[illegible]
[illegible]	[illegible]						JAN [illegible]		Transistor	Q1

DELCO ELECTRONICS DIVISION • SANTA BARBARA OPERATIONS • GENERAL MOTORS CORPORATION

DWG NO. SK 002405

REV A

REVISIONS				
LTR	DESCRIPTION	AUTH.	DATE	APPD
A	REVISE SCHEMATIC & RELEASE		9-17-80	V.S.T.

REVISION	A	A	A	A	A																							
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF DOG	ENGR		STARTUP & PROTECTION No 2 A22
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO 13160 · DWG NO. SK002405 · REV A
CONTR NO.	OTHER APPD		SCALE · WEIGHT · SHEET 1 OF 5

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CLASS ____.

PARTS LIST

CONTRACT NO.	CODE IDENT NO. 13[illegible]	[illegible]	[illegible]
LIST TITLE: Start-Up & Protection No. 2 [illegible]	AUTHENTICATION	REVISION NOTICE NO.	REV DATE

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	NOTES
1	1						CK06BX[illegible]K		Capacitor, C[illegible]	[illegible]
2	1						CK06BX[illegible]		[illegible]	[illegible]
3	2						M39014/[illegible]-23[illegible]		[illegible]	[illegible]
4	1						M49[illegible]-22[illegible]		[illegible]	[illegible]
5	1						M390[illegible]-23[illegible]		[illegible]	[illegible]
6	5						RCR07G510JS		Resistor 51K [illegible] 5%	[illegible]
7	2						RCR07G[illegible]JS		[illegible]	[illegible]
8	2						RCR07G[illegible]JS		Resistor [illegible] 5%	[illegible]
9	1						RNC55[illegible]5513FM		Resistor [illegible] 1%	[illegible]
10	1						RNC55[illegible]2943FM		Resistor 294[illegible] 1%	[illegible]
11	1						RNC55[illegible]33FM		[illegible]	[illegible]
12	1						RNC55[illegible]FM		[illegible]	[illegible]
13	2						RNC55[illegible]FM		Resistor [illegible]	[illegible]

PARTS LIST

CONTRACT NO	CODE IDENT NO	
	13160	[illegible]

LIST TITLE: Start-Up & Protection No. 2 A22

AUTHENTICATION | REVISION NOTICE NO | REV DATE

ITEM NO	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	REMARKS
14	1						RNC55H6982FM		Resistor, 69.8K, [illegible]	[illegible]
15	2						RNC55H1504FM		Resistor, 1.5M, 1/8W, [illegible]	[illegible]
16	1						RNC55H2552FM		Resistor, 25.5K, 1/8W, 1%	[illegible]
17	2						RNC55H[illegible]FM		Resistor, [illegible]K, 1/8W, 1%	[illegible]
18	1						RNC55H[illegible]FM		Resistor, [illegible], 1/8W, [illegible]	[illegible]
19	1						RNC55H6812FM		Resistor, 68.1K, 1/8W, [illegible]	[illegible]
20	1						RNC55H[illegible]FM		Resistor, 523K 1/8W, 1%	[illegible]
21	3						RCR07G[illegible]JS		Resistor, [illegible] 1/4W, 5%	[illegible]
22	1						RCR07G[illegible]JS		Resistor, [illegible] 1/4W, 5%	[illegible]
23	1						RCR07G103JS		Resistor, 10K, 1/4W, 5%	[illegible]
24	1						20M-[illegible] 1/4 [illegible]		Resistor [illegible] (Var)	[illegible]
25	5						JAN 1N[illegible]		Diode [illegible]	
26	2						JAN 1N[illegible]		Diode [illegible]	

PARTS LIST

CONTRACT NO.	CODE IDENT NO.		REV LTR
	[illegible]	[illegible]	[illegible]

LIST TITLE: Start-Up & Protection [illegible] A32

AUTHENTICATION	REVISION NOTICE NO.	REV DATE	SHEET
			1 OF

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
27	13						JAN 1N4148-1		[illegible]	
28	1						LM140K		I.C.	[illegible]
29	7						LM195K		I.C.	[illegible]
30	1						LM124D		I.C.	[illegible]
31	1						LM150H		I.C.	[illegible]
32	2						MM5[illegible]		I.C.	[illegible]
33	1						CD4043		I.C.	[illegible]
34	1						CD4[illegible]58		I.C.	[illegible]
35	1						LF[illegible]H		I.C.	[illegible]
36	1						CD 4051		I.C.	[illegible]
37	1						CD 4072		I.C.	[illegible]
38	1						CD 4012		I.C.	[illegible]

REVISIONS

LTR	DESCRIPTION	AUTH.	DATE	APPD

DWG NO SK002406

REVISION	+	+	+	+																								
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF DO6	ENGR RFS	5/31/79	REGULATOR A23
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK002406 · REV +
CONTR NO.	OTHER APPD		SCALE · WEIGHT · SHEET 1 OF 4

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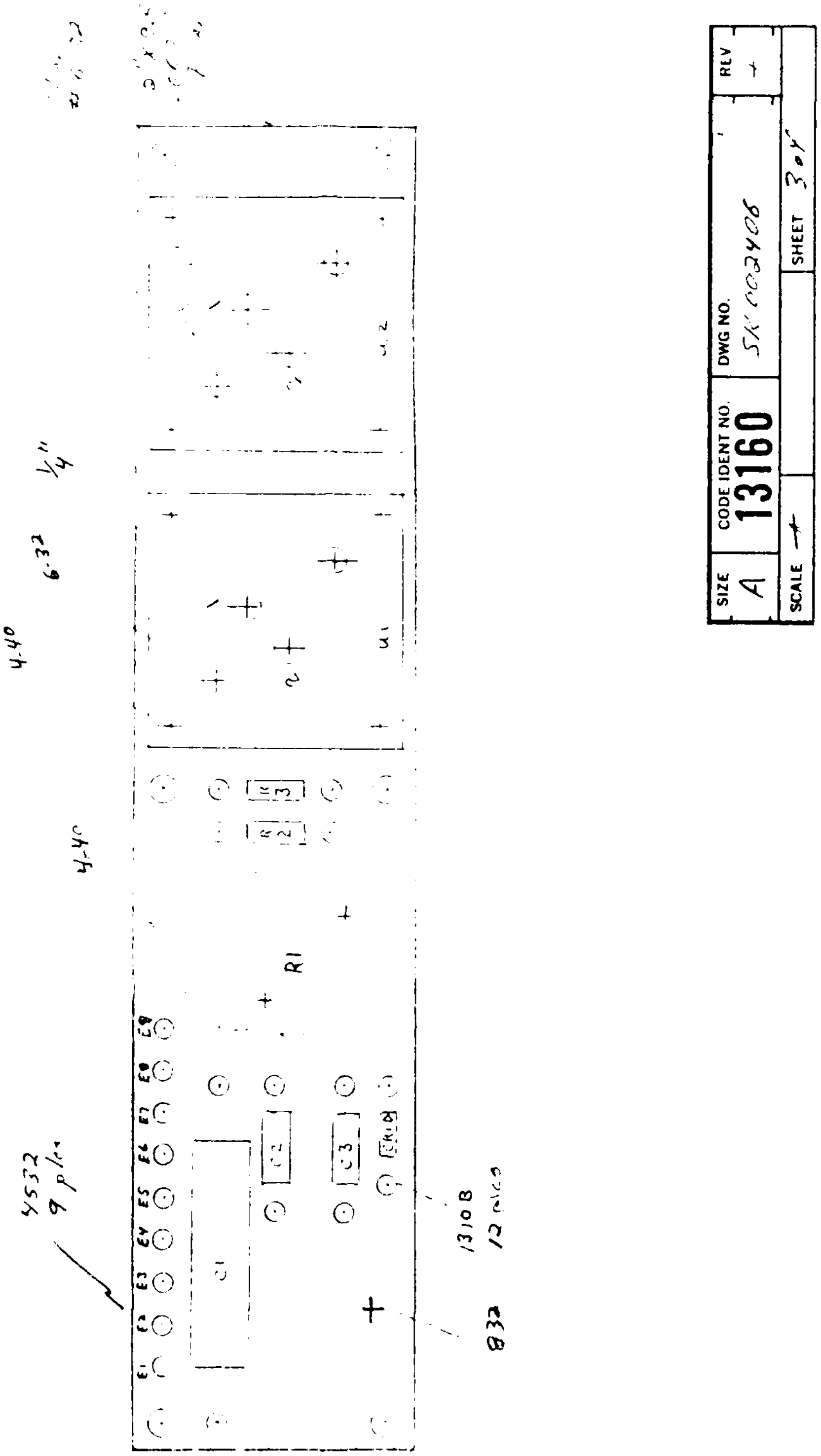
CLASS ____


SIZE
A
CODE IDENT NO.
13160
DWG NO.
SHEET
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R1
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E5
E6
E7
E8
E9

PARTS LIST

LIST TITLE REGULATOR A23	CONTRACT NO	CODE IDENT NO 3160	SK002486	SHEET	
	AUTHENTICATION	REVISION NOTICE NO	REV DATE	SHEET 4 OF	

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1	1						JAN 1N5552		Silicon Rectifier, CR1	
2	1							—	Capacitor, 100µF, 50V Al. Electro. C1	
3	2							—	Capacitor, 1.2µF, 50V Solid Tant.; C2, C3	
4	1						RCR07G3161FM		Resistor, 3.16KΩ, .25W R2	
5	1						RCR07G2370FM		Resistor 237Ω, .25W R3	
6	1						—	NH-10	Resistor, 0.1Ω, 2%, 10W R1 (Dale)	
7	1						LM109K		IC, U2	
8	1						LM150K		IC, U1	
9	2						680-1.0A		Heatsink, Wakefield	
10	1								Heatsink, Wakefield	
11	9						4552		Turret Term. USECO	
12	12						1310 B		Bifurcated Term. USECO	

DWG NO. SK022414

REV +

REVISIONS				
LTR	DESCRIPTION	AUTH.	DATE	APPD

REVISION	+	+																										
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF D06	ENGR RFB	5/13/…	BLOWER ASSY A29
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK022414 · REV +
CONTR NO.	OTHER APPD		SCALE · WEIGHT · SHEET 1 OF 2

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CLASS ____.

PARTS LIST

PARTS LIST	CONTRACT NO.	CODE IDENT NO. 13160	SL 202414
LIST TITLE BLOWER ASSY A 29	AUTHENTICATION	REVISION NOTICE NO.	REV DATE

ITEM NO.	QTY REQD -011	QTY REQD	QTY REQD	QTY REQD	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1	3					02660	760120VZ282		Blower, 110V, 50/60 Hz	
2	1						SK002309-028		Plate (Lock)	

DWG NO. SK002291 REV -/-

REVISIONS

LTR	DESCRIPTION	AUTH.	DATE	APPD

REVISION	-/-	-/-	-/-	-/-	-/-																							
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMS. ARE IN INCHES	DFTSMN / DSGR KOSTUSAK	25 SEP 78	**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	CHK		
REF 006	ENGR	NOV 2 1978	PANEL, CONTROL ELECTRICAL COMPONENTS
	APPD		
CHG CONTROL	APPD		
	DSGN ACTIVITY		SIZE A · CODE IDENT NO. 13160 · DWG NO. SK002291 · REV -/-
CONTR NO.	OTHER APPD		SCALE — · WEIGHT · SHEET 1 OF 5

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CLASS ____.

PARTS LIST

CONTRACT NO:

CODE IDENT NO: 13160

SK007291

LIST TITLE: PANEL CONTROL ELECTRICAL COMPONENTS

AUTHENTICATION:

REVISION NOTICE NO:

REV DATE:

4

ITEM NO.	QTY REQD	QTY REQD	QTY REQD	QTY REQD -011	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NO. SEL
1				1			SK007291-001		PANEL, FRONT	
2				1			TBA		AMMETER (M1)	
3				1		77221	627-14717		VOLTMETER (M2)	
4				1			MS27407-5		SWITCH, TOGGLE (S1)	(MASTER)
5				1			MS24523-22		SWITCH, TOGGLE (S2)	(PNL LIGHT)
6				1			MS24523-27		SWITCH, TOGGLE (S3)	(CONT.)
7				1			TBA		SWITCH, ROTARY (S4)	(METER SEL)
8				1			MS24524-26		SWITCH, TOGGLE (S5)	(LAMP)
9				1		29604	736567		SWITCH, ROTARY (S6)	[illegible]
10				1			RA20SASD102A	MIL-R-19	POT (R1)	
11				6			LH89/1	MIL-L-3661/47	LAMP BASE (DS1 → DS6)	
12				4			LC35RN2	MIL-L-3661/35	LENS (RED) (DS1 → DS4)	
13				2			LC35GN2	MIL-L-3661/35	LENS (GRN) (DS5, DS6)	

PARTS LIST

CONTRACT NO	CODE IDENT NO		REV LTR
	13160	SK002291	A

LIST TITLE: PANEL, CONTROL ELECTRICAL COMPONENTS

AUTHENTICATION	REVISION NOTICE NO	REV DATE	SHEET
			5 OF

ITEM NO.	QTY REQD	QTY REQD	QTY REQD	QTY REQD -011	UNIT OF MEAS	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	DRAWING OR SPECIFICATION NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
14				1		72619	47-3202-2900-301		LAMP ASSY (DS7)	
15				1			MS25041-4		LAMP ASSY (AMBER) (DS8)	
16				7			MS25237-387		LAMP	
17				1		03508	656D-24V		LAMP	
18				1			MS91528-2N2B		KNOB (R1)	
19				2			MS91528-2P2B		KNOB (S4, S6)	
20				2		65092	9808-150754		GASKET, METER	
21							MS9021-012		"O" RING (.369/.359 I.D)	
22							MS9021-013		"O" RING (.431/.421 I.D.)	
23							MS9021-016		"O" RING (.619/.609 I.D.)	

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